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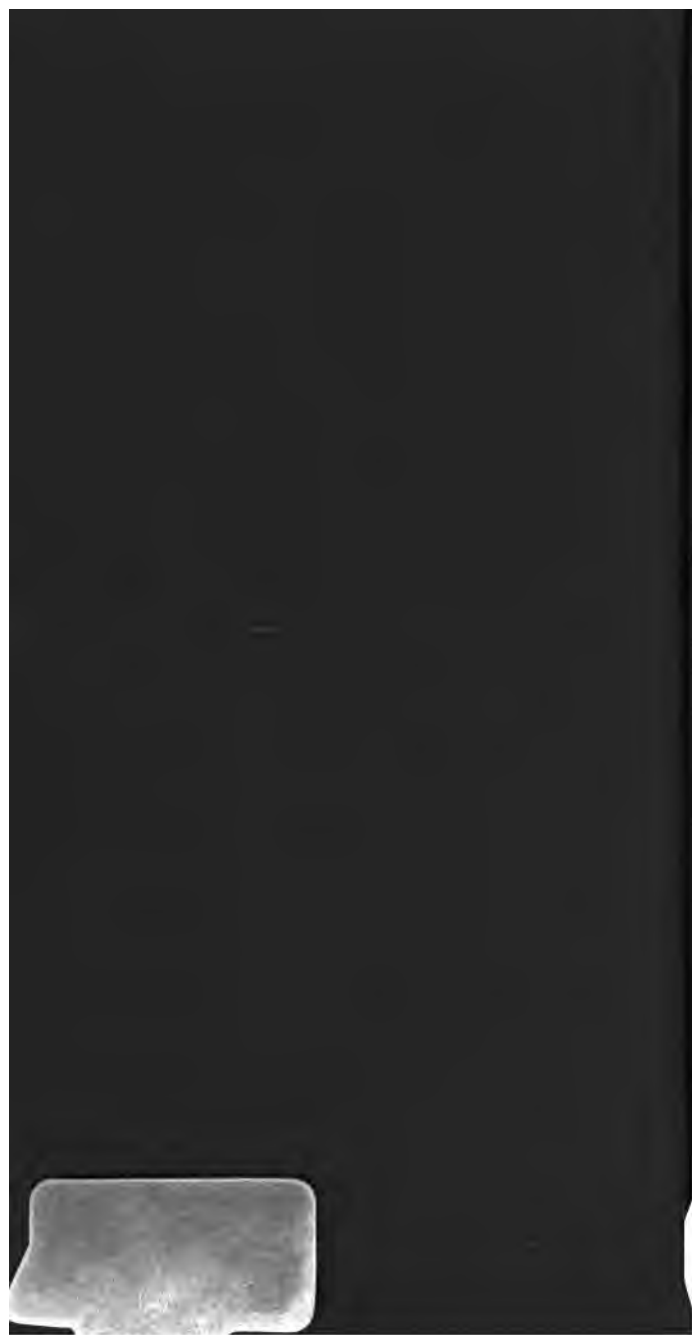
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ELECTRIC LIGHT
ITS PRODUCTION AND USE

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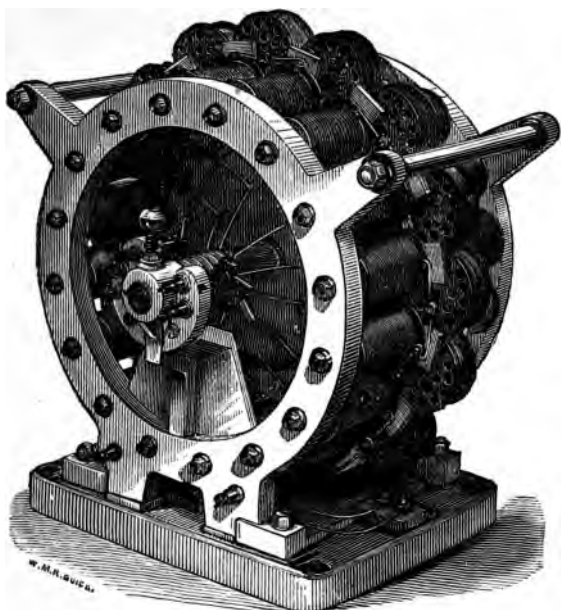
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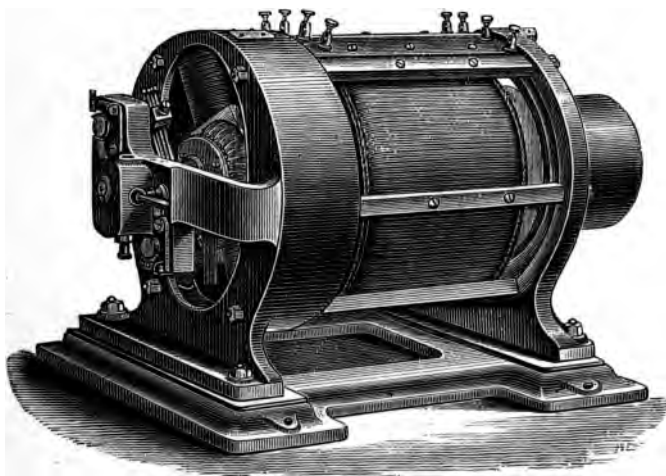
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Siemens' Twelve-light Alternating Current Machine, as used at the British Museum. [See p. 130.]



Gramme's Combined Exciting and Dividing Machine. [See p. 116.]

ELECTRIC LIGHT

ITS PRODUCTION AND USE

EMBODYING

PLAIN DIRECTIONS FOR THE TREATMENT OF
VOLTAIC BATTERIES, ELECTRIC LAMPS,
AND DYNAMO-ELECTRIC MACHINES

By J. W. URQUHART, ELECTRICIAN

AUTHOR OF "ELECTRO-PLATING: A PRACTICAL HANDBOOK;" ETC

EDITED BY

F. C. WEBB, M.I.C.E., M.S.T.E.

WITH NUMEROUS ILLUSTRATIONS

Second Edition, carefully revised, with large additions



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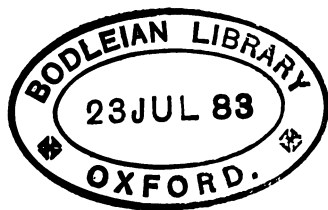
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1883

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CITY ROAD.

PREFACE.

IN the first issue of this work, which appeared in 1880, a general view of the means then employed in the production and application of the electric light was given. No attempt was then made to deal exhaustively with the subject. In the present edition, although the work has necessarily been in great part re-written, the aim of the author has again been to preserve as far as possible the essentially simple character of the descriptive portions rather than to offer an exhaustive treatise on the subject.

Several additions have been made to the present issue of the work, the most important of which is a new chapter on circuits, or leading-wire systems. Much of the original text has been removed and its place filled by new matter relating to the more recent developments of the art of electric lighting. On the other hand, care has been taken to retain the accounts of the earlier developments of electric machines and lamps, so that the interesting successive steps which have led up to the systems now used may be studied by the reader in conjunction with recent discoveries.

Within the past two years the art of electric lighting has advanced most rapidly, and results have been attained of which the earlier electricians could scarcely have dreamed. These developments have taken effect in the source of electricity, the distributing system, and in the electric lamp. Not only have "incandescent" lamps been brought to a high state of perfection, so rendering domestic electric lighting practicable, but the older "arc" lamps have undergone such improvements, that electric distribution by either system may now be regarded as no longer a problem.

As may have been expected, an infinite variety of electric machines, distributing systems, and lamps have of late appeared. It was, therefore, obviously impossible to give descriptions of every kind of electric lighting appliances within the limits of the present treatise. But care has been taken to select for treatment prominent examples of machines, carrying systems, and lamps embodying the chief points of interest or practical value.

No apology need therefore be offered for the non-appearance of several machines and lamps in this work. Of electric accumulators much has not been said, for although they are a valuable auxiliary to the dynamo-electric machine, they have not as yet been very extensively used in electric lighting. The systems of electrical measurements have not been treated upon; for descriptions of these, the reader is referred to the numerous existing text-books of electricity.

The author has to acknowledge having received much assistance from his friend, Mr. F. C. Webb, Memb. Inst. C.E. and M.S.T.E., who in this case, as in that of the first edition, kindly undertook the arrangement and supervision of the work in its progress through the press, and who has made many valuable suggestions and additions. From Messrs. Siemens Bros. & Co., the Brush Electric Light Corporation, the Edison Company, Messrs. Crompton, and other leading electricians, he has also received much assistance.

JOHN W. URQUHART.

LONDON, January, 1883.

NOTE BY THE EDITOR.

In revising for the press the second edition of this book, I have found with much pleasure that the additions now made by the author constitute a comprehensive and reliable account of the principal advances made in Electric Lighting since the publication of the first edition.

F. C. WEBB.

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ELECTRIC LIGHT.

CHAPTER I.

INTRODUCTION.

IF the extremities of two wires forming the poles of a powerful source of electricity are brought into contact and again gradually separated, the electric current continues to flow across the narrow separation, accompanied by an intense evolution of light and heat. The distance to which the electric poles may be separated without interrupting the continuity of the circuit depends upon the electromotive force of the source and the total resistance of the circuit; it is seldom more than one-fourth of an inch. The air between the two poles becomes heated and is the primary cause of the conduction of the current across the breach.

The brilliant belt of light thus produced has been termed the *voltaic arc*. If the two poles consist of charcoal or graphite, the luminosity of the arc is greatly increased. The light in this case is supposed by some to be partly due actually to combustion of the carbon, particles of which fly off

from one carbon to the other. On the other hand, it has been pointed out that the incandescence is still more intense in a vacuum, or in any of the gases that do not support combustion, than in the ordinary atmosphere, so that the phenomenon is not to be considered as one of simple combustion. A brilliant light can also be obtained by passing powerful currents through metals of low conducting power, such as platinum, or through thin pieces or filaments of carbon. In all cases of the production of the voltaic arc or electric incandescence, it will be found that a great resistance to the current in a small space has to be overcome by the source of electricity.

The date of the earliest production of the electric light is somewhat uncertain, but in 1810 Sir Humphry Davy, with a battery of 2,000 elements, exhibited at the Royal Institution the electric light with an arc 3 inches long between carbon points.

The following is the account given in the *Philosophical Magazine*, vol. xxxv., for Jan. to June, 1810, p. 463 :—

“In the concluding lecture at the Royal Institution, the large voltaic apparatus, consisting of 2,000 double plates of four inches square, was put into action for the first time. The effect of this combination, the largest that has ever been constructed, was, as might be expected, of a very brilliant kind.

“The spark, the light of which was so intense as to resemble that of the sun, struck through some

lines of air, and produced a discharge through heated air of nearly three inches in length and of a dazzling splendour. Several bodies which had not been fused before were fused by this flame; the new metals discovered by Mr. Tennant, iridium, and the alloy of iridium and osmium, zircon, and alumine, were likewise fused; charcoal was made to evaporate, and plumbago appeared to fuse *in vacuo*; charcoal was ignited to intense whiteness by it in oxymuriatic acid gas, and volatilised in it, but without effecting its decomposition."

With regard to this, Professor Daniell, whose elegant and careful writing is still worth quoting at the present day, remarks: *—"The disruptive discharge of the voltaic battery through air is dependent upon precisely the same principles as that of the Leyden battery; but the phenomena are modified by the lower intensity, greater quantity, and perpetual renewal of the force. When passing between two charcoal points, its duration renders it the most splendid source of light which is under the command of art. When the poles of a powerful battery are gradually separated after contact, the discharge takes place through an interval which increases with the heating of the air by the ignited charcoal. With the original battery of the Royal Institution of 2,000 plates, the discharge passed through four inches of air; and with the constant battery of 70 cells the flame is much more voluminous, and extends to the distance of one inch.

* "Chemical Philosophy," p. 460.

"It would, however, appear that the air is not the only form of matter which is concerned in the phenomena, but that particles of the solid electrodes contribute to the general effect by convection. It is probable that the superior brilliancy of the phenomena with charcoal may be owing to the larger number of its solid particles which its small cohesion enables it to throw off in the process. The colour of the light varies with the substances between which the discharge passes. Gold leaf gives white tinged with blue; silver, a beautiful emerald green; copper, bluish white light with red sparks; lead, a purple; zinc, white fringed with red.

"The arc takes place with great brilliancy under the surface of distilled water; some electrolytic effect will at the same time occur, but the greater part of the charge will pass in a brilliant stream of light."

For many years the light only remained a little more than a scientific toy, being occasionally used for lecture purposes, or for the illumination of the microscope; but the discovery of the means of producing electricity in large quantities from mechanical motion through the intervention of magnetism, instead of by chemical action, gave this branch of electric science a new starting-point, and at the present day electric lights on a large scale are entirely produced by currents generated by the rapid movement of insulated wires through a magnetic field. In all arrangements for the production of the electric light we require first a source or

generator of electricity; secondly, conducting wires; and thirdly, an arrangement of carbons or metals, at which the light is actually emitted, called the lamp. We shall commence, therefore, by descriptions of the generators employed; and as electricity from voltaic batteries was first employed for the electric light, it will be more in accordance with the history of the subject to commence by describing this means of producing electricity for the benefit of experimenters, notwithstanding that the production of the light by the currents produced by what may be termed electro-mechanical means is, at the present day, by far of the greater importance.

We shall, however, again allude to the voltaic arc and the phenomena of electric incandescence when treating of the various arrangements of lamps.

CHAPTER II.

VOLTAIC BATTERIES.

As a source of electricity for permanent electric lighting the voltaic battery is practically useless. It is frequently required, however, to produce small voltaic arc lights for the illumination of the optical lantern, the microscope, and other instruments of that description. Although the voltaic battery is somewhat costly in working, and is generally considered a troublesome source of electricity, it may in some cases be made extremely useful for experimental and lecture purposes. Very few laboratories and lecture-rooms are as yet supplied with dynamo-electric machines or other sources of powerful currents. It is probable, therefore, that for some years to come the voltaic battery will be used in many of the minor applications of the electric light. In such instances it may be considered a handy and even inexpensive source of electricity.

The theory of the voltaic battery and the laws appertaining to the voltaic circuit are not treated of in these pages. The many excellent text-books of electricity adequately supply this want. A very slight acquaintance with electricity will enable the

novice to use a voltaic battery. Unless the young experimenter adopts certain precautions, however, it is not unlikely that he may find this source of current both costly and troublesome. On the other hand, an acquaintance with the working of the battery may enable him to employ it without inconvenience. As a source of small currents for experimental and testing purposes, he will find a voltaic cell almost indispensable.

Voltaic batteries of a type suited to the production of the electric light are few in number. The batteries that are generally employed in working telegraphs or ringing house-bells, or even in electro-plating, are all too weak for our purpose.

We require a battery of small size to supply for a short period a very energetic current of electricity. We also must have a generator that will not vary much in power during about two hours. It should be inexpensive at first, and in working its cost must be low, while it should not give any trouble during the time the light is required. It must not waste its materials, but give all the benefit derived from the consumption of zinc as current.

All batteries consist of one or more cells, in which are placed two substances, the one more oxidisable than the other, and acted on by acids more or less diluted. The most oxidisable substance is termed the positive element, and the other the negative element. Electricity of opposite name is believed to flow off in contrary directions

in equal quantities from the surface of generation, viz., the junction of the liquid with the positive plate; but for convenience, the current is supposed to flow from the positive element through the liquid to the negative element, thence from the terminal on the negative element through the external circuit of wire, earth, or other conductor back to the terminal of the positive element. The current is supposed, therefore, to leave the battery at the *terminal attached to the negative element*, and this terminal, or the end of any wire attached to it, is termed the *positive pole*.

In the same way the *terminal or wire attached to the positive element* is termed the *negative pole*.

Construction of Batteries.

Positive Elements.—In nearly all batteries the oxidisable metal, or positive plate or element, is of zinc, and the current is therefore produced by the slow consumption or combustion of zinc, which is, therefore, our fuel. Its cost is about fourpence per lb. The best zinc for this purpose is that known as rolled Belgian. The plates or cylinders should be about $\frac{3}{8}$ ths of an inch in thickness, and in electric light batteries must be amalgamated; that is, coated with a closely adherent film of mercury. Zinc, when new from the rolling mill, is greasy, and this film should be dissolved off in a hot solution of caustic soda. To cut zinc plates to size is a more difficult matter than is generally

supposed. The simplest way is to make a deep scratch at the place of separation, repeat this on the opposite side, and run mercury into the cut. This will soak nearly through in a few minutes, and the plate may be divided by bending over the edge of a table. To bend zinc plates into cylinders it is only necessary to heat them in hot water and curve them over a wooden cylinder.

A question now arises as to whether the zinc plate is to be provided with a *binding-screw*, or is it to have a copper strap soldered to it? Binding-screws are procurable of all kinds. Some are made for soldering to zinc plates, and others for screwing upon them.

Fig. 1 represents some specimens of binding-screws, of which the smallest, with rounded head, is best suited for screwing upon plates and cylinders of zinc. For soldering, the same screw is made with and without plain stems. Conducting straps of copper should be cut from sheet, and of uniform width, with a length of 5 inches. They are usually attached to zinc cylinders for use in Bunsen's cell. It is by far best to drill a hole in the zinc and strap, and to securely rivet the latter to the cylinder. The joint should be quite firm,

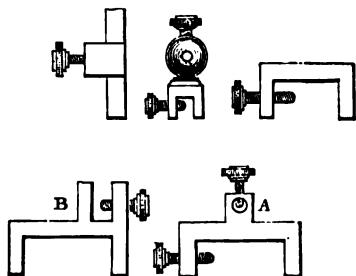


Fig. 1.—Binding-screws and Clamps.

the copper where it touches must be *clean*, and a coating of japan or other varnish will protect the connection from corrosion.

When a connection is to be soldered, a tinman's "iron" should be used, although the blow-pipe is frequently employed for this purpose. The flux generally consists of a weak solution of chloride of zinc. The solder itself is a mixture of tin and lead, generally known as "soft solder." In connections between copper wires, or copper and brass, it is advisable to use resin as a flux. Joints made in copper cables with the aid of zinc chloride have been known to become "rotten."

To amalgamate zinc, dip the plate for a minute in acidulated water, one to ten; pour the mercury into a shallow vessel, and, while the zinc surface is wet, distribute the mercury upon it with a pad of cotton or tow until a perfect surface is secured, and the mercury covers the plate. If there are parts where the mercury will not "take," dip the plate again into the dilute acid and repeat the process; finally, set the plate up on edge to drain off the superfluous mercury.

If the plate is not amalgamated, "local action" will reduce the current in strength and waste a great deal of the zinc. The mercury connects the various impurities of the zinc together, and prevents the local action from commencing. After use, if the plates show black patches, they should be re-amalgamated.

Negative Plates.—Receiving or negative plates in

electric light batteries are usually of the dense variety of carbon known as graphite, found in gas retorts after gas-making. It may be scaled off. Its price at the gas-works is trifling, as it is, otherwise than for batteries, of little use. The best carbon, which aids the development of the current, is very hard, of a grey colour, and dense crystalline structure. It is, therefore, very difficult to cut, and unless proper appliances be at hand, in the shape of a revolving disc of iron, fed with silver-sand and water, it will be found cheaper to buy the plates and blocks from the instrument-dealers.

The Excitant is, as a rule, sulphuric acid diluted with much water.

Containing Cells.—The containing cells hold from half a pint to a gallon. Quart size is very well suited for electric-light batteries. The single-liquid cells have only one containing vessel, while those that are double have two. Outer cells may be made of glass, but, as a rule, glazed earthenware is stronger and more suitable. When a considerable number of the cells is required, it will be found that the makers can supply them at a much cheaper rate than the instrument-dealers.

Porous Cells are of unglazed earthenware. They are made usually in two shapes—round tubes, long and narrow, and in oblong form, for use in Grove's battery. They are placed within the zinc cylinder, or U-shaped plate, and usually contain the carbon block, or plate. In Grove's cells, a strip of platinum foil is used.

Such cells, to be suitable for electric-light purposes, must not be hard and dense, while the thickness of the sides should in no case be over $\frac{3}{16}$ ths of an inch. The softest are of red-ware ; but better cells, and sufficiently porous, are made from white clay. A test of the porosity should be taken by placing water in the cells, and allowing them to stand for some time. If, after about 15 minutes, a dew does not appear on the outside of the cell, it is probably too hard or thick, and will offer too great a resistance to the current. If, on the other hand, the water actually runs off the side, the cell is *too* porous, and will shorten the period of the action of the battery by too rapid transfusion of the liquids into each other. This mixing action is sometimes called *endosmosis*, although it is also applied to the peculiar creeping of solutions of metallic salts, such as the copper sulphate used in Daniell's cell. Porous cells are easily procurable of instrument-dealers.

Composition of a Cell.—A voltaic cell must be composed of two dissimilar metals or materials immersed either in one or two liquids. The one-liquid cells, although convenient enough for short experiments, so rapidly acquire a film of gas upon their negative plates that the development of the current is speedily impeded, and consequently such cells, unless the excitant is agitated in some way, are unfitted for supplying current for any length of time.

In the two-liquid cells the negative plate is sur-

rounded by a liquid rich in oxygen; hence, the hydrogen, which is, in single-liquid cells, set free at the negative plate, is, in such a double-fluid cell as Grove's, absorbed by the oxygen of the nitric acid. In the more effective two-fluid batteries the negative plate is by these means kept quite free from a film of hydrogen. This fault in single-fluid cells is generally known as polarization. It will be of interest to observe that what is here a fault is really the fundamental principle of the various electric accumulators, secondary or storage batteries lately introduced.

Two-liquid cells are, however, more troublesome, and may be set aside in favour of single-liquid ones for many short experiments.

Bichromate Cells.

Fig. 2 shows, in principle, the way in which three or more of the bichromate of potash cells are made up. They are composed of two carbon plates, having between them a zinc plate, amalgamated. The plates are contained by a glass or earthenware vessel of the shape shown, and a dozen or two of such cells, about six inches

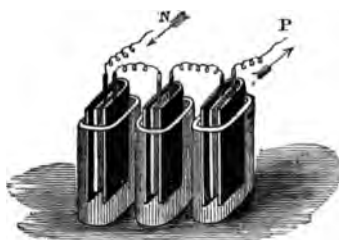


Fig. 2.—Simple Voltaic Cells.

high, form a very powerful and useful battery in short experiments. This engraving is, however, only intended to illustrate the construction of single cells, and the manner in which they are connected together.

Whenever two plates are used in a single cell, and are held by a brass clamp, such as that shown in the illustration of binding-screws, they must be separated from contact with each other by having placed between their upper edges a strip of wood, pasteboard, or other non-conducting material. The three cells here shown form a battery of three cells joined in series, that is, zinc to carbon and zinc to carbon throughout. The two carbon plates are connected together by a strip of copper, and therefore one wire from either one of them takes off all the current. Both sides of the zinc evolve electricity, which passes through the *liquid* to the carbon plates, and so by the negative plate wire, as shown by the arrow and marked P. Thus the negative plate wire is the positive wire or pole, while the zinc plate wire, being the receiving or returning end of the battery, is called the negative wire or pole, as shown by N, and the arrow indicating the flow of the current.

Two wires thus convey the current from a coupled-up battery of cells, and scarcely any action commences within the battery until the ends of these conductors are brought together in metallic contact, or until some circuit, such as that of one composed of wires and an electric lamp,

is provided for the electricity to flow from and back to the battery.

For electric arc light purposes it is generally best, up to 50 cells, to join up in series—zinc, carbon, zinc, carbon; but this will be further spoken of in connection with Bunsen's cell.

A plate of zinc between two plates of carbon then forms a single element of the battery. A brass clamp may bind the whole together, the zinc being prevented from contact with the carbon by strips of wood as thin as possible, while the two carbons are connected as one by the brass clamp. Elements, or sets thus made up, can be charged with dilute sulphuric acid only, and for bell-ringing, telegraphy, or testing, with a solution of sal-ammoniac; but for electric light purposes, requiring a powerful current, the containing vessel should be three-fourths filled with a mixture as follows :

Crystals of bichromate of potash	3 oz.
Warm water	1 pint.
And (when cool) sulphuric acid	2 oz.

When this liquid is fresh, it causes the pairs immersed in it to give off a great deal of electricity—that is, a strong current. The potash salt is in reddish crystals, and costs about 1s. per lb.

Pairs of bichromate of potash cell plates should not be immersed in the solution until the current is really required and all is ready. Of course, all the pairs, joined up by spirals of wire, may lie near the cells until the time comes for placing them in the liquid; but a much better device, and a most

convenient and cheap containing cell, is exhibited in Fig. 3. Bottles of this shape, and to contain



Fig. 3.—Battery Cells.

about a quart, are easily procurable. The neck should be sufficiently large to admit the pairs of plates, while the liquid is not readily splashed over the top. Attached to one of the cells is shown a stout brass

collar, A, soldered

around the neck tightly. To this is securely attached an upright stout brass wire, bent as shown at B. The object is, of course, to provide a convenient hook upon which to suspend the pairs of plates when removed from the liquid. All the cells should have this arrangement, and may be put out of action in a moment by pulling up and hooking the plates by their wire or in a loop soldered on the clamp.



Fig. 4.—Small Bichromate Cell.

Fig. 4 exhibits a more expensive and elaborate form of the bichromate of potash cell. It is very handy for experiments, and requires little at-

tention. The pair of carbon plates extend down-

wards from the wooden or ebonite cover of the bottle to the bottom, and remain permanently in the liquid. The carbon is not injured by this continuous immersion. The liquid will *keep* any length of time, but the time it will *work* is, of course, limited to perhaps 15 minutes, if the bulk be small. The zinc plate is attached to a sliding rod, movable in a split brass tube fastened to the cover, and may thus be lifted clear of the liquid, so as to throw the cell out of action. This prevents waste of the zinc and the solution.

The carbon plates are made fast by screwing or riveting to stout angular pieces of copper, and these being connected together, and having soldered to them the stem of a binding-post, one wire serves as before for both plates. The split tube is connected by a strip of copper or brass to the other binding-screw. The ebonite cover—or a wooden cover will do equally well—is furnished with a brass collar to fit over the neck of the bottle.

Fig. 5 exhibits another shape of bottle, of larger size, as usually employed in the construction of cells of great capacity. The zinc should be as large as possible, and its top should be furnished with a piece of ebonite cut to fit between the carbon plates, to prevent the zinc from twisting and closing the circuit within the cell.

The art of working bichromate cells consists, first, in never leaving or placing the zinc in the solution when the current is not required, removing it the instant the experiment is performed, and in

not leaving it in the liquid for over five minutes without either disturbing the liquid or moving the plate. The great defect of such cells is the want of circulation in the liquid, so that, when the liquid is allowed to remain quite still, the current is soon weakened. If heat can be applied, so as to cause some circulation, the current will come off almost



Fig. 5.—Bichromate Cells.

in full even flow until the solution is exhausted. Exhausted solutions may be thrown away, or they may be allowed to spontaneously evaporate, when the chrome alum formed in the action may be recovered. This salt is of value in dyeing.

All the connecting wires should be insulated, and at least as thick as No. 16 Birmingham wire

gauge. All connections must be clean and metallic; electricity will not pass through dirt, coatings of oxide, or cotton covering. Connecting points in clamps should be occasionally examined, to prevent imperfect contact. Bad connections will weaken the current, and sometimes stop it altogether. To give some convenient elasticity, the connecting wires may be wound on a rod to

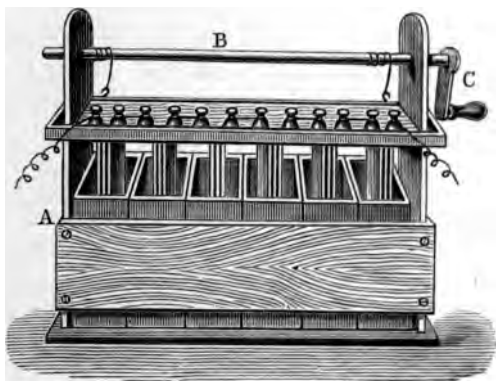


Fig. 6.--Six-cell Lifting Battery.

form a spiral; but too much wire must not in this way be introduced into the circuit, or the current will be weakened by its resistance. All connections to lamp or instruments should be thick, or No. 12 copper wire. All uninsulated wires must, of course, be kept from contact together, otherwise the circuit may be closed outside the battery before it reaches the electric lamp or other instrument.

Fig. 6 is a form of bichromate battery in much favour, as it admits of a great number of plates

being placed in and withdrawn from the liquid at one movement. The arrangement also permits of the easy agitation of the liquid. The author has seen a battery of this kind of 25 quart cells give a beautiful electric light for a considerable time by an ingenious arrangement of a weight, wheel, and lever rocked by a crank applied to the lifting-gear. In this way the plates were raised a little way, and then dropped, every second, thus agitating the liquid—the result being a steady current.

A is a wooden frame, accommodating as many oblong glazed cells as may be required. The plates are all attached to a wooden holder above them as exhibited, above which are attached the binding-posts as in other forms of the cell. This holder is capable of sliding vertically upon A, by means of the handle and spindle with cords, B and C.

Number of Bichromate Cells required.—This depends upon the amount of light required. A light will be given by 6 cells of quart size, but it will be a small light, and will not permit of any actual separation of the carbon points; 12 cells will yield much more than double the light, and 24 will admit of actual separation, giving the true voltaic arc and a very brilliant light; 50 cells will give rise to a voltaic arc of great splendour, probably equal to 1,500 candles.

It may be said that, up to 50 cells of the quart size, it is generally advantageous to connect up in series for use with ordinary electric lamps.

The electromotive force of 50 cells is usually sufficient, and any greater number of cells should be connected in parallel circuit to an equal consecutive number of cells of the 50 elements, so as to reduce the internal resistance of the battery whilst maintaining a sufficient electromotive force. Thus, if there are 100 cells, each 50 should be joined up in series, and then the negative wires from both should lead to one screw of the lamp, and both positives to the other screw. Thus the electromotive force of the battery is not increased, but the resistance of the elements that are doubled is halved. But of course the most advantageous mode of grouping a given number of elements must depend on the resistance of the external part of the circuit; for with a given number of elements they should be so joined that their internal resistance shall equal the external resistance. It will be unwise to expect over half-an-hour's continuous light from any bichromate of potash battery; and there must be agitation of the liquid to get even this amount of light. The solution may be refreshed afterwards by the addition of 2 ozs. of sulphuric acid to the pint.

Constant Batteries.

Bunsen's Cell.—The original battery invented by Bunsen consisted of a cylinder of carbon for the negative element; and the zinc, in the form of a cylinder also, was placed within the porous cell. This form is expensive to make, and also more

expensive in use than that now known as the Bunsen cell.

Fig. 7 is a view of a Bunsen cell of approved construction. The outer vessel is of glass. The positive element consists of a cylinder of thick sheet

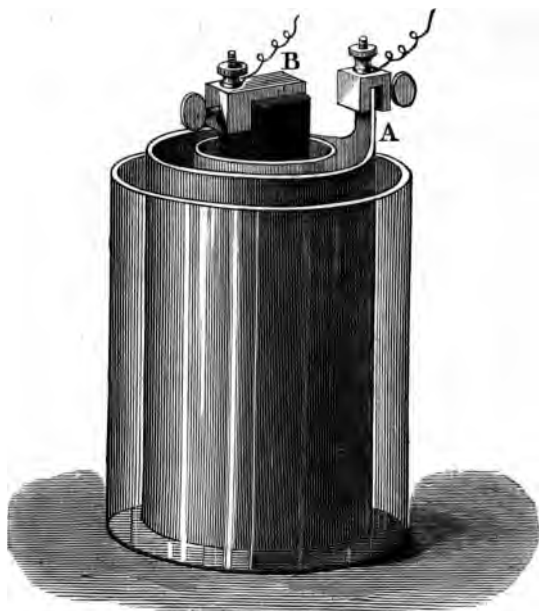


Fig. 7.—Bunsen Cell.

zinc, to fit loosely into the outer vessel. A is a projection left upon the zinc in the process of cutting it to size ; it serves to provide a fastening for the binding-screw clear of the liquid. The screws are of brass. Within the zinc cylinder is a vessel of porous earthenware, as before indicated, and in

this porous vessel, completing the cell, is placed a cylindrical or square block of gas carbon, with a binding-clamp, B, fastened to it.

It may be as well to preface further remarks upon this generator with the assurance that, with one exception, it is the only real producer of voltaic currents that can be cheaply applied and depended upon in the production of electric light. Its current, once started, is almost constant for about 4 hours, and a good light may, with confidence, be depended upon for 3 hours.

The roll of zinc, A, should not be a *complete* cylinder. The edges should not come quite together; a division, however narrow, should be left while bending. Both inside and outside of the cylinder should, and indeed must, be amalgamated, as is done with flat plates, and care is necessary to renew the amalgamation as soon as black patches are observed to form upon the surface.

As to the actual making up of Bunsen generators, as here exhibited, the outer cells should contain nearly a quart of liquid at least. They are best made of brown well-glazed earthenware, as before recommended. The zinc cylinders should be cut to the size in the flat sheet, leaving the stem for the screw upon them for connection, and then bent over a wooden former while hot. The porous pots should be higher than the zinc, and the zinc should be higher than the outer cell. A soft porous cell is the most suitable, of white or red materials. Within the porous cell is placed the carbon block, which

should be highest of all, and may be either round or square; but square blocks are almost always used, and are easily procurable at about $\frac{3}{4}$ d. per inch in height, retail. A hard, clear, grey carbon should be chosen, and black and porous varieties rejected, because they add to the resistance of the circuit and reduce the force otherwise.

It is a common practice simply to clamp the carbon by a binding-clamp of brass for the connection. This is, however, when the cell is to be used much, a bad and decidedly troublesome way of getting contact. It is by far better to give the block a heading of lead. To do this, dry the head, cut a notch or two around it $\frac{1}{4}$ in. from the end. Melt the lead and pour it into some square mould, such as a cavity made in hard putty or plaster of Paris. Before the lead sets, dip in the carbon end, and allow the whole to solidify before removal. While still hot, the binding-screw may be soldered on, and before it cools the whole should receive a coating of melted pitch; or, which is much better, dip the head in melted (solid) paraffin, which, when cool, will effectually defend the connection from outside attacks of the acid.

A better way still, although not so quickly accomplished, is to electrotype a heading of copper upon the rods, to insure the best possible connection. To do this, partly fill a porous pot with acidulated water; place this in an outer cell containing crystals of copper sulphate dissolved in warm water. Heat the rods, and give them a coating of

paraffin, driven in with a hot iron, between where the liquid will reach up to and where the heading will reach down to. If any paraffin spreads upon the end, drive it back by heating; cut now a few notches in the head as before, and drill a hole right through, in which place tightly a piece of stout copper wire, having $\frac{1}{4}$ in. of the end projecting at each side. Tie a wire around the carbon block, at the end of which fasten a strip of zinc, which place in the porous cell, while the carbon head dips into the copper solution. As soon as this is done, a deposit of copper will begin to form upon the wire and carbon, and when it has attained a thickness of good brown paper, remove the block, drill two holes right through the copper and carbon, soak a little time in warm water, dry off, and place for some time in melted paraffin to obtain an efficient protection. The binding-screw may be soldered to the copper, which will be found of the greatest utility as a heading which cannot be attacked by the acid.

The exciting liquids are:—

In the outer cell, with the zinc . . . 1 part sulphuric acid; water, 4.

In the porous cell, with the carbon . . strong nitric acid only.

This "charge" will work the cell for about 4 hours. After this the outer acid will have exhausted itself; but the nitric acid, which will have turned from a clear liquid to a reddish colour, may be used again. The second time of using will turn it green, and the third time quite clear again, when it should be thrown away and

replaced by fresh. It is no economy to use nitric acid of inferior quality; it should be concentrated, and costs, when good, about 10d. per lb., retail.

The Bunsen, while at work, gives off the fumes of the nitric acid, which renders it necessary that the battery should be placed out of doors, or in a place where there is a draught of air. These fumes are poisonous; they are worst while the porous cells are being emptied into the nitric acid stock bottle, but may be quite avoided in the open air.

In the working of large batteries of the Bunsen cell, some special arrangements are required to enable the attendant to get through the work of charging quickly and accurately. First, the sulphuric acid mixture must be prepared in a large bottle beforehand, by pouring the acid into the water — *not the reverse* — and stirring. It is most convenient to have a graduated measure, by means of which the correct quantity of nitric acid may be determined before placing in the cell. This is of more importance than might at first seem to be necessary; but a measure that can be quickly and easily filled to a known point, and as speedily emptied into the cells, will not only be cleanly, but will prevent spilling the nitric acid into the zinc compartment, an accident which sets up violent local action upon the zinc. It will first be necessary to find how much liquid will fill the porous pots to within one inch of the top when the carbons

are placed in them, and then to fill all the cells with the carbons and zincs near at hand. It is further of consequence to have the liquid within the porous cell at the same height as that in the outer pot.

The battery should not be put in action until within a short time of its being required. A dish of water should be at hand in the case of accident by burning the hands with nitric acid, and it is well for the attendant to have in use his oldest clothes, because nitric acid will, if dropped upon them, destroy the part. Quickly place the zincs and carbons in their respective cells first, and then go backwards over the series, making the connections with certainty. See that each screw is well home, and that there is no bad connection throughout. As to the time such operations occupy, a battery of 50 Bunsens may be unpacked, put into action, and the light produced within twenty minutes.

When the porous cell of the Bunsen battery is charged with a strong solution of the bichromate of potash, as recommended for the single-liquid cell, its force is very little diminished and the fumes of the nitric acid entirely avoided. Of late, most experimenters have abandoned the use of nitric acid in favour of the chromic acid.

Again, in pulling the battery to pieces after operations, all the connections should first be loosened; then the zincs should be placed one by one in a bucket of water to wash off the acid. The carbons are next similarly treated, and after

putting a funnel in the neck of the nitric acid bottle, the porous pots should be emptied one by one, and then plunged in water. The outer liquid may be thrown away, as it is useless, or nearly so. Porous pots should, after once being used, be kept in water for a few hours to soak out any nitric acid or zinc sulphate, which, while dry, would crack them. All connections should be well washed and dried, and before again using should be looked to for oxidized or bad contact points, which must be scraped bright or filed.

Zinc cylinders showing black patches should be again amalgamated, but this will probably be unnecessary until after the third time of using.

The force of the Bunsen will increase after setting up for about an hour, and the full effect will not be attained until the acid soaks through the porous pot. Carbons, as in bichromate batteries, are not affected in the least, and will last any length of time. The zinc is consumed slowly, through the mercury coating.

Twenty-five cells of the Bunsen will give a very brilliant light, and 50 will produce an arc of great power, while 100 will, when coupled in two parallel circuits of 50 each, so as to give an electromotive force of 50 and a resistance of only 25, produce effects of the most splendid character. The conducting wires must be thick—about No. 12, and even stouter conductors should be employed when 100 cells are used, joined up in parallel circuits of 50 each.

Fig. 8 is a view of a pair of superiorly finished Bunsen cells, for laboratory use. They are fitted with removable screws upon both the carbons and zincs. The containing vessels are of glass. This engraving exhibits the separation which should be made between the edges of the zinc cylinder. This separation is chiefly for the purpose of preventing the formation of local currents in the zinc, while it also assists the outer liquid to more freely circulate.



Fig. 8.—Pair of Bunsen Cells, showing connections.

Various arrangements of the Bunsen cells may be adopted in making up a handy battery. The framework and lifting arrangement spoken of in connection with the bichromate cell is also applicable to the Bunsen. There is, however, one disadvantage in the two-liquid cells, and it consists in the diffusive tendency of the two liquids, whether the cells are in action or not. It is thus almost impracticable to arrange a rackwork frame for the Bunsen, so as to obtain the convenience of the arrangement to the extent previously described in reference to the bichromate. It is better, however, to have the means of lifting the elements out of their cells, as it is useful when the battery is put

into action for short experiments extending to about one and a half hours. During this time no great mixture will have taken place, and the zincs and carbons, arranged on the lifting-board just above their respective cells, may be lowered as required. There are some advantages in the frame used in this way. Bunsen batteries are most convenient when put up in long boxes while in action.

Iron Cells.

With the primary idea of effecting economical working, a cell has been tried, the invention of Mr. Slater, and others. All that can be here said of it, as well as of every other form of cell in which iron is employed yet introduced, is that they are entirely unfitted for use in inexperienced hands. The iron cell is objectionable in many ways, but its chief fault would appear to be the tendency of the acid in the iron compartment to boil over when least expected. Such cells are, moreover, false economy, as will be found on working them for electric light, although the first cost may be lower than that of the Bunsen.

Chromate of Lime Cells.

To replace the potash salt with greater economy and equal power in working, a cell of the double-liquid kind has been devised by Messrs. Fitzgerald and Molloy, which is said to be about as constant

as the Bunsen, while it is almost as effective in working, and is undoubtedly cheaper when properly made.

The chief point in the construction is to secure as large a negative surface as possible, and, by means of a soft porous cell, to reduce the internal resistance of the combination.

Several forms of make-up have been tried. The best is a cylinder of carbon surrounding a large porous cell containing the zinc as a cylinder. Carbon cylinders are difficult to make. The graphite must be ground finely, or that deposited as powder upon the retorts may be used direct. It must be mixed into a stiff dough with water and sugar syrup, then baked until hard, and, while still hot, plunged in a strong solution of sugar or tar, and finally heated to whiteness and cooled slowly.

Another construction of the cell is arranged as follows:—A large soft porous cell is taken, in which is placed centrally a thin rod of carbon, or a Bunsen rod, with a screw affixed. Around the rod is packed a quantity of broken carbon in lumps as large as hazel-nuts. Over the top is run melted pitch, and a conical hole is left for the introduction of the liquid. The outer vessel, as in the Bunsen, contains a cylinder of zinc, and its diameter should be only just enough to admit the porous cell freely, the object being to have the zinc near to the negative element. In order to allow the outer liquid greater freedom of action, the zinc cylinder should have a separation of about

$\frac{1}{2}$ in. The cell is thus a carbon and zinc one, like Bunsen's. The exciting solutions are, however:—

FOR POROUS CELL.

Chromate of lime	.	.	.	.	.	2 ounces.
Warm water	.	.	.	.	.	5 „
Sulphuric acid	.	.	.	.	.	5 „

FOR THE OUTER CELL.

Water	.	.	.	.	.	1 pint.
Sulphuric acid	.	.	.	.	.	3 ounces.

The action will be found to give off little or no fumes. The electro-motive force is slightly greater than that of the Bunsen; but the internal resistance is also greater.

This same cell is available for use with another excitant, which will be found to work even with greater force, and give little or no fumes for the first two hours:—

FOR THE POROUS CELL.

Bichromate of potash	.	.	.	.	.	2 ounces.
Nitric acid	.	.	.	.	.	10 „
Sulphuric acid	.	.	.	.	.	2 „

In the outer cell the solution is the same as for the Bunsen. This will be found to work with greater power than the Bunsen, owing to the arrangement of the carbon, and the internal resistance is less, but the cost of working is rather greater. After use the porous cells should be emptied of their contents, and kept in water until again wanted. The same solution may be used two or three times, and if there be any appear-

ance of a poverty of potash salt, more should be added.

Various modifications of such cells may be used. As a rule it is best to provide a strongly acid mixture for the carbon compartment. Thus the cell above mentioned, as its construction is virtually the same as the Bunsen, may be used with great advantage as a Bunsen, and it will give a greater current than the common forms, while the cost of construction is very little more.

Cells Too Weak.

Avoid attempting to produce the electric light with the following cells:—Daniell, Smee, Manganese, Sulphate of Lead, Sulphate of Mercury, Chloride of Silver, Marie Davy (mercury sulphate cell), Copper-Zinc (simple), Minotto (modification of Daniell), Léclanché, Grenet, Highton, Clark's Mercury, Peroxide of Iron, Perchloride of Iron, Calland's, Spiral Cell, Meidenger (modification of Daniell), and, in short, all cells used for telegraphy or bell-ringing.

The Grove Cell.

This cell admits of a very large and powerful battery being placed in a very small compass. Grove's cell is like the Bunsen, except that platinum foil is employed instead of carbon. The solutions are the same—that is, strong nitric acid in the porous pot with the platinum foil, and acidu-

lated water in the zinc cell. To obtain the greatest power, it is most effective when made up in cylindrical vessels like the Bunsen.

Fig. 9 represents the zinc cylinder of a Grove cell.

Another make-up, adapted to the purposes of lecturers and where great portability is necessary, is shown in Fig. 10, where A is the zinc plate, in a

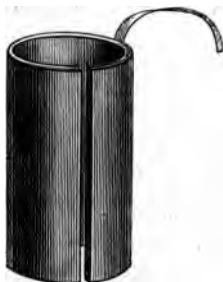


Fig. 9.—Zinc Cylinder.

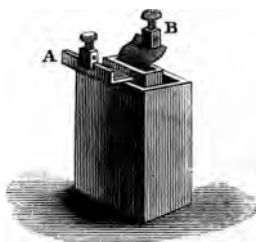


Fig. 10.—Grove's Cell.

flat outer cell, and B the platinum foil plate, in a flat porous vessel.

Fig. 11 exhibits these cells with the elements removed. Porous cells of this kind are more expensive than round ones. They should be thin in the sides, but the ends and bottoms for strength may be thicker with advantage.

Fig. 12 shows how the zinc plate should be bent, so that it may embrace the porous cell closely. The generator has thus a great deal of zinc surface. To increase the otherwise somewhat small surface of the platinum plate, it should be corrugated, or simply very much wrinkled; but it is

better to corrugate it in the direction of its length, which will both increase the effective surface and add to its stiffness. Fig. 13 shows the platinum plate arranged for the cylindrical zinc of Fig. 9. A is a cover of wood or ebonite to which the plate is made fast, and a connecting strip leads to the binding-screw holder, B, which is of brass or copper sheet, bent at right angles, and secured to the wooden cover by two screws. It is a mistake to purchase platinum foils too thin. There is no

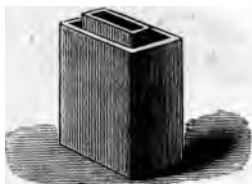


Fig. 11.—Pots for Grove's Cell.

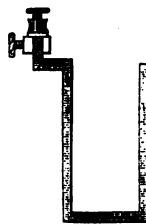


Fig. 12.—Zinc for Grove's Cell.



Fig. 13.
Platinum Plate.

waste, but foil that is like tissue-paper is a source of constant trouble.

The chief objection to the use of platinum is its great cost, as it is not procurable as sheet or wire under £1 10s. per oz.; but an ounce of platinum will go a long way in foil of sufficient thickness for use in the Grove cell. The connection may be soldered on, but it is usually better to solder on a clamp-piece of sheet-copper first, across the top edge; and to protect this metal from the fumes of

nitric acid, it should be coated, while warm, with Brunswick varnish, or sealing-wax dissolved in warm methylated spirit of wine. Any kind of clamps or screws may be used, but it is most convenient to have them removable.

Fig. 14 shows a ten-cell Grove's battery, as used by lecturers for the production of small electric lights. It is composed of the flat cells, and the foils are clamped by plain clamps to the succeeding zincs throughout.

The resistance of Grove's battery is very small,

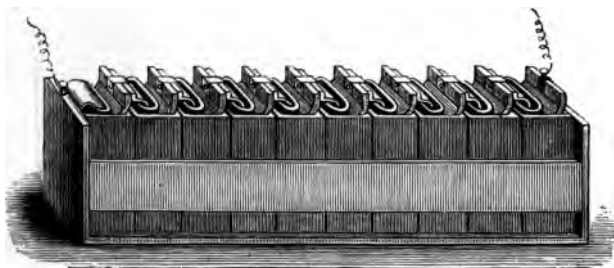


Fig. 14.—Ten-cell Grove's Battery.

and on this account it will give, size for size, a stronger current than the Bunsen when the external resistance is small, although the difference does not warrant the extra expenditure except for travelling purposes, or when space is limited. A Grove's cell will cost about three times as much as a Bunsen. Twenty Grove's cells, or two cases of ten as the one shown, will give a good light, and five such cases of ten, coupled up in series, will produce effects of great grandeur.

It is of greater importance than with most other

cells to have the conductors and connections used in Grove's batteries very stout and of good soft copper. The time this battery will remain in action is about the same as that given by the Bunsen. The Grove cells may be smaller than the Bunsen to produce the same effects. The same care is necessary in keeping the zinc amalgamated, and the bottom, or bend, is usually better rounded and should be well watched for worn portions or patches becoming unamalgamated. Less nitric acid than is used in Bunsen's will be sufficient in the Grove cells. The author has used Bunsen cells made up in Grove vessels with every success for operations extending over $2\frac{1}{2}$ hours. Plates of carbon must, of course, be used instead of blocks, and they should be as thin as may be convenient. This make-up is more expensive than that of the common shape of Bunsen. Grove porous cells should have a lip at one corner for convenience in pouring out the contents.

Battery for Photographer's Light.

It has long been known that the electric light is rich in actinic rays, and on this account it is of much value to the photographer in securing views of places and objects not reached by the light of the sun, or in the practice of portraiture.

It may be said that a good electric light will be found to work the rapid dry plates of to-day almost as easily as daylight at noon.

Since the introduction of cheap dynamo-electric machines, and the new gas-engines of Crossley and Otto, photographers in various cities have taken up the new light, and at the present time it is an easy matter to get a portrait taken at night in more than one place in Regent Street and elsewhere. Very few photographers, however, can afford to go to the necessary outlay of about £110 for a gas-engine and machine with lamp.

The author has devised, in a modification of Dr. Byrne's negative plate cells, a voltaic generator free from most of the objections generally urged against the application of batteries. It is at first inexpensive, is easily managed and certain in results, and its maintenance low enough in cost to warrant its extensive use. It is, further, very portable, and may be made use of in travelling to secure photographs of caves and such places. It is not procurable commercially, and the intending user is therefore recommended to make it for himself, for which purpose full instructions are given, with an illustration of the apparatus.

Assuming that the reader, from glancing at previous pages, is sufficiently acquainted with the usual construction of a voltaic cell to understand readily minor details not here mentioned, it will be best to premise further remarks with an explanation of the nature of this new generator. It is, then, a simple bichromate of potash cell, with negative plates of a peculiar construction, and so arranged that a very powerful current may be

obtained from even 6 cells by the aid of much agitation by air.

Each negative plate consists of a plate of copper, to one surface of which, as well as to its edges, a sheet of platinum foil, compact, and free from pin-holes, is soldered, and to the opposite surface or back, a sheet of lead—the three metals being so united that the copper shall be effectually protected from the action of acids. The lead back and edges are then coated with asphaltum varnish, acid-proof cement, or any other like substance; and lastly, the platinum face, being first rubbed over gently with emery cloth, is to be thoroughly platinised.

To Platinise.—Fill a containing vessel and a porous cell with acidulated water, and place the porous cell within the large vessel. Tie a strip of zinc by a clean wire to the plate to be platinised; dip the zinc in the porous cell, and the plate in the outer cell, and drop into the outer cell, while stirring, a solution of platinic chloride in water. Add drop by drop, with agitation, until the platinum surface is seen to turn dark, and to have acquired a granular deposit of platinum. Upon this surface depends to a great degree the power of the generator. If any difficulty is experienced in securing a good deposit, dip only a little of the zinc in the solution at first, and increase as the coating is seen to form. Dry carefully, and do not scratch the plate or remove the deposit, which it is not difficult to do before it is dry.

Each cell contains two such plates, between

which a single zinc is suspended, and when the elements are immersed so that the exciting fluid reaches to within an inch of the top, a large negative surface is brought into action.

It will thus be seen that the platinum alone is the negative, or receiving metal, and the copper core a conducting body merely; while the lead, being almost passive, serves no other purpose than to protect the copper, so that any other, and, best of all, a non-metallic substance capable of resisting the action of bichromate solutions, might, with advantage, be substituted for the lead. The exciting solution to use in this cell is prepared as follows:—

Bichromate of potash	.	.	.	.	2 ounces.
Warm water	.	.	.	.	1 pint.
And, when cool, sulphuric acid	.	.	.	.	4 ounces.

Fig. 15 represents a six-cell generator of this kind. The cells are the ordinary brown glazed earthenware oblong ones used for the Grove and other batteries. They should be capable of containing at least a pint of the liquid; quart cells will be found more economical. There are three plates in each cell—two platinised plates, and one amalgamated zinc between them. They are separated at their top edges by slips of wood or ebonite, against which they are securely clamped by stout brass clamps as shown. Thus the brass clamp, being in metallic contact with the lead, with clean scraped surface, represents them both as the positive pole. To the zinc plate in the

centre is soldered a common binding-screw. Very stout and soft copper wires—about No. 12—must

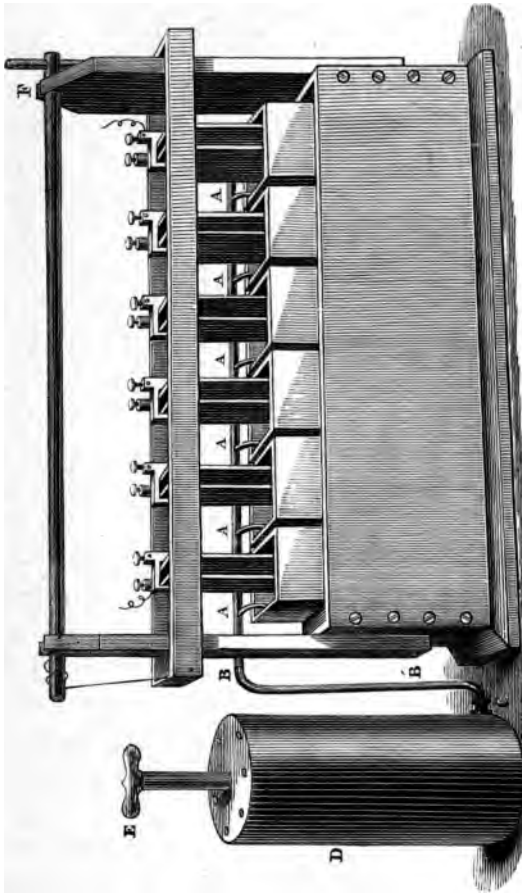


Fig. 15.—Richromate Pneumatic Battery.

be used to connect up the elements in series, zinc to platinum, zinc to platinum, and so on, with

clean contacts. The sets of plates are fastened to a framing of wood, made to slide up and down the side uprights by means of an overhead shaft, cords, and handle F. This allows of the plates being drawn out of the solution the instant they are out of action to save zinc and solution, as previously described for common bichromate batteries. A ratchet wheel should be put upon the spindle, with adjustable pawl, to hold the plates in position when drawn up. For quart cells the plates may be 8 in. long by $4\frac{1}{2}$ wide.

The air-distributing arrangements of this apparatus are as follow:—A A A is a piece of $\frac{1}{2}$ -inch lead piping, fastened to the back of the framework, from which lead, as shown, 6 smaller tubes ($\frac{1}{4}$ -inch) of rubber or varnished lead. These extend to the bottom of the cells, and then run parallel with and directly under the plate edges. The ends are closed, and the horizontal portion is perforated with many small holes. B B is a rubber pipe slipped over the end of A, its other end being made secure to the outlet, C, of a hand-pump D, worked by the handle E. The air-pumping arrangement exhibited in the figure is not very effective—it is irregular in action.

There must be a valve at C to close the passage to A when the handle is drawn up; otherwise the solution would be pumped out of the cells. The whole should be screwed to the floor, or have a projection upon which to place the foot for steady-

ness. It is better to use one of Fletcher's foot-blowers.

If these elements are lowered into the solution simply, it will be found that a much greater power is obtainable from them than that given by zinc-carbon batteries, previously mentioned. The full effect, however, for which this valuable battery is remarkable can only be obtained by pumping in air by the small tubes. A great disturbance of the liquid results, and the current is so much augmented in power that even a 6-cell battery will yield a light equal to that given by a 20-cell Bunsen or Grove.

The air disturbance has no effect upon the electromotive force of the battery, although the volume of current given off is enormously increased, and any other means of effecting the required agitation would probably answer the purpose equally well. The suggestion of Professor Adams as to the air effecting a free circulation in the fluid, by which the metallic surfaces are kept constantly clear, is undoubtedly the correct explanation. The wonderful effects are in great part due to the low internal resistance of the cell, owing to the peculiar arrangement of negative plate, partly to the peculiar effect of a rapid flow of air upwards through the liquid, and partly to the production of heat. The action of the air-flow is principally mechanical, but by hastening the combustion of the zinc it tends to generate heat, which in turn reduces the resistance. The mechanical action of the air is to remove from

the neighbourhood of the negative plate the chrome alum which is formed there, and from the surfaces of the zinc plate the zinc sulphate, formed by its union with the sulphuric acid; and to bring a fresh supply of solution constantly to the surfaces.

With a battery of 10 cells, a platinum wire, 32 in. long, of No. 14 gauge ($\cdot 089$ -in. in diameter), was gradually brought to a glowing red heat, which ebbed and flowed with the cessation or renewal of the air-flow. A brilliant electric light is maintained between two carbon points, which similarly varies in intensity with the flow of air, so that it is important to pump the air in regularly; and when this can be done by a crank attached to a heavy fly-wheel, almost perfect regularity is secured. The effects which are ordinarily produced by 60 or 70 Grove or Bunsen cells were obtained from 10 cells of this battery in the laboratory of Mr. Spottiswoode, F.R.S., at Sevenoaks.

To prevent the possibility of any disappointment in the use of this apparatus, it may be as well to inform the reader at the outset that for every 15 minutes or so of electric light the solution in the cells will become nearly exhausted. A battery of 20 cells produces a most powerful current, which will be nearly constant if the air-flow is maintained continuously.

Secondary Batteries or Accumulators.

When we pass an electric current through a cell composed of two plates of the *same* metal plunged in dilute acid, a result ensues which may be assumed to be the storing up of a certain percentage of the electric energy. That an accumulation of electrical force (or force capable of becoming electrical) has actually taken place may be demonstrated by disconnecting the secondary cell and closing its circuit through a galvanometer. A powerful rush of current is at once indicated, having a direction opposed to that of the primary current. If we examine the plates while still in the condition of electrical accumulation, it is found that a portion of the water has been decomposed into its constituents, the gases being deposited as a layer, or cushion, upon the two plates. The oxygen appears upon the positive plate, or that by which the current enters the cell, and the hydrogen upon the negative plate, or that by which the current leaves the cell. The hydrogen film is found to be electro-positive to the oxygen film, and a certain amount of potential energy is conferred upon the two cushions of gas, so that when we connect the plates by a conductor it is ready to become free in the form of a current, and so restore the equilibrium of the two films, which become recomposed into water, and the cell is once more at rest.

A German physicist, named Ritter, was the first

to construct a battery from which these secondary currents could be obtained. In 1859 M. Planté discovered that sheets of lead yielded effects of considerably greater duration than those obtained from plates of platinum, which was usually employed by Ritter. He also discovered that by continuing the charging current for a sufficient time a peroxide of lead was formed upon the positive or oxidised plate, and hydrogen was deposited upon the negative plate. It was found that when this stage was reached the charge accumulated by the cell was very considerable, and that the element possessed a much higher electromotive force than any of the ordinary voltaic generators. M. Planté also found that in the course of the yielding up of the energy stored the oxidised plate became deoxidised, and that its oxygen passed through the liquid to the negative plate, attacking and oxidising it. The positive plate, which had thus been oxidised and become deoxidised, presented the appearance of spongy lead, and so offering an enormous extent of surface to the action of the current. Each time the cell was used its capacity for storing electric energy was increased, until both plates were in the spongy state, and the accumulator had attained its fully-formed condition, as it was termed.

These observations led M. Planté to considerably extend the surfaces of the lead plates employed in the cells. He next placed canvas between two large, thin plates and rolled them up in a close

spiral. They were thus separated by a short space, but insulated from each other. The spiral cylinder was then plunged in dilute acid, and the charging current passed for some time. The cell was then discharged and the current passed through it as before, but in the opposite direction; again discharged and allowed to rest for a day or two, until the oxide formed had time to become rigid. The operation of forming the cell thus extended over some length of time, and its capacity for storing electric energy increased with each removal. When once fully formed, the cell had only to be connected to a pair of suitable voltaic batteries to receive a charge of considerable power, which might be carried about and used at pleasure. The advantage of this secondary cell consisted in the powerful current it evolved, with a low internal resistance and of high electromotive force.

M. Faure, in 1881, turned his attention to the possibility of still further extending the valuable researches of M. Planté, and acting upon the hint afforded by the fact that in the Planté cell a peroxide of lead had formed upon the plates, and that its thickness partly determined the capacity of the cell, tried the effect of coating the lead plates direct with a thick cushion of *minium*—a kind of red-lead. This peroxide was mixed into a thick batter with dilute acid, and the plates so treated were separated by cloth or felt, and rolled up in a spiral or arranged in rectangular troughs. The result was not only a combination which was at

once ready to receive a charge, but it possessed the advantage of having a greater accumulative capacity than the first cells of M. Planté. This ready method of forming the cells gave great impetus to the development and employment of secondary or storage batteries, and to the introduction of many other forms of voltaic accumulator.

At the present time the secondary batteries of M. Faure are extensively used, as are those of other inventors, for storing electrical energy for use, as in the electric lighting of railway trains, &c. The secondary battery is also frequently employed as a regulator or magazine in connection with dynamo-electric machines for electric lighting. The batteries are generally charged by means of a current from a dynamo machine. But the anticipations of several eminent electricians, in reference to this kind of electric accumulator, have as yet only been but partially realised. In some instances the secondary battery has been used for the propulsion of tram-cars through the medium of electro-motors.

CHAPTER III.

THERMO-ELECTRIC BATTERIES.

MUCH has been done, and much more remains to be accomplished in the generation of electricity for illuminating purposes by heat and combinations of metals.

A current of electricity is produced in a circuit composed of two different metals when their junction is heated. The metals which exhibit this property to the greatest degree are bismuth and

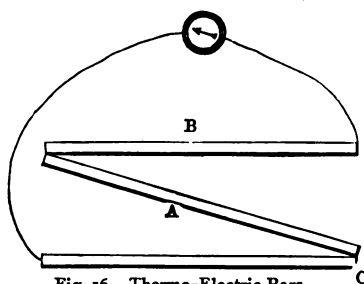


Fig. 16.—Thermo-Electric Bars.

antimony. If two bars of bismuth, B and C, and one of antimony, A, are placed as in Fig. 16, and heat applied at one junction while the other is cooled by radiation or otherwise, a current will flow into the wires and through the galvanometer.

The two most efficient thermo-electric piles in use up to 1876 were probably those of MM. Clamond and Nœe ; great numbers of such pairs being employed to multiply the force and current.

By the expenditure of 21 lbs. of coke per hour, M. Clamond, of Paris, has succeeded in maintaining four electric lights, each having an illuminating power of 220-standard candles. This is vouched for by the Count du Moncel; and, indeed, there should be nothing impossible, or even difficult, in the accomplishment of such a result. Sixty couples will yield, when well constructed, a current equal to a gallon Bunsen cell, and less than 3,000 elements will give the effects of 50 Bunsens with an expenditure of 80 cubic feet of gas per hour. Such results are reported of the couples of M. C. A. Faure.

M. J. E. M. Sudre, who has been working in conjunction with M. Clamond, has taken out a patent for the following advances in the make-up of thermo-electric batteries.

1. For the construction and arrangement of thermo-electric chains composed of couples, the resistance of which has been reduced to a minimum.

2. The combination and arrangement of the chains with two metallic plates, of which the opposing surfaces are coated with an insulating layer; which plates form part of two metallic systems, one serving to collect and communicate the heat, and the other to abstract and diffuse it.

3. The combination and arrangement for binding, coupling, and insulating the thermo-electric chains, when several are mounted side by side between the two plates.

4. The application and use of the collector and diffuser to any description of thermo-electric piles, so as to maintain the necessary difference of temperature between the extremities of the couples without lateral waste of heat.

One of the main features of the invention, as described, is the maintenance of the necessary difference of temperature between the two solderings of each couple by placing those couples between two surfaces from which they are electrically insulated. It is stated that in the construction of thermo-electric couples and chains, an isolated thermo-electric couple is ordinarily composed of a prism in metal or alloy casting and of a polar plate of iron, copper, German silver, or other suitable metal soldered to each of its extremities. The plates do not ordinarily interfere in the slightest with the electric force obtained, and it is the bar, such as that of antimony and zinc, which produces the effect.

When it is desired to use two metals or energetic alloys of which the effects are combined, and which are easily fusible, such as bismuth and antimony, the couple is then formed of two bars, which are joined together by a cross bar which binds them and is soldered to each of them.

The total resistance of a couple is composed,

1st, of the resistance of the connecting plate; 2nd, of the resistance of the bar, ordinarily composed of alloys sufficiently resistant, and 3rd, of a particular resistance at the points of contact or soldering between the plates and the bar. The metallic plates should be of a metal sufficiently conductive, such as copper, iron, German silver, &c., and should be sufficiently large and thick to present but a feeble resistance. They should also be as short as possible. These conditions, it is claimed, are realised in the improvements of M. Sudre. Again, the bar should have very little resistance under a small volume. The inventor takes as a datum the formula $R = k \frac{L}{S}$, in which k is a specific co-efficient for the metal employed, L the length of the bar, and S its section. As the resistance depends on the ratio $\frac{L}{S}$, the volume of the couple may be diminished by diminishing the length and sectional area in equal degrees, in which case the resistance will not be affected.

The length which should be given to the bar depends upon the difference of temperatures employed. For differences of temperature between 10° and 120° (Centigrade), M. Sudre gives to the couples a length of 10 or 12 millimètres, whilst if the higher temperature reaches 300° the length varies from 20 to 30 millimètres. The resistance at the points of contact or soldering is of the highest importance. The junction should be made so that

the plate is in contact with the whole section of the bar. The plate should penetrate to a very little depth within the bar, so as not to diminish too much the electro-motive force of the couple ; for the really effective difference of temperature is that of the two solderings, and this difference diminishes as the plates penetrate more deeply into the bar, and thus approach one another.

In constructing the couples M. Sudre cuts the extremities of the connecting plates in the form of a comb, the teeth of which are afterwards twisted so as to present a helicoidal surface, which holds the plates, as it were, screwed into the bars. The cut portion of the plates is so adjusted in a mould that the teeth become embedded in the bar when this is cast. A considerable number of bars are cast simultaneously, and constitute a thermo-electric chain. The external portion of the plates is coated with asbestos-paper, mica, terra-cotta, or other suitable insulating material, which may be cemented to the metallic surfaces by means of silicate of soda solution.

The chains are arranged in battery between two metal plates, which may be plane or curved. Each of the plates is kept cool on one of its surfaces by means of a thin layer of some bad conductor of heat. One of these plates constitutes the collector and the other the diffuser. In order to maintain the diffusing surface at a low temperature, M. Sudre employs a cooling-box of water, fed from a tank.

An important question remains yet to be solved as regards this pile, and that is the amount of maintenance and repairs required by it. Should these be of low cost, a generator very well suited to purposes of artificial illumination will result.

CHAPTER IV.

MAGNETO-ELECTRIC GENERATORS.

IN the year 1831 Professor Michael Faraday made one of those brilliant discoveries which have immortalised his name, and has formed the starting point of all those ingenious electro-mechanical engines of the present day for converting the energy stored in fuel into light. Arguing that as from electricity in the electro-magnet he obtained magnetism, so from magnetism there must be a means of obtaining electricity, he experimented with his usual skill and patient perseverance, and was rewarded by the discovery of what has been termed magneto-electricity. He found that if a magnet was moved near a coil of insulated wire forming a circuit, a current of electricity was induced in the circuit during the movement of the magnet.

Fig. 17 illustrates, in a simple way, the manner in which the generation of an electric current may be brought about by means of a magnet and coiled wire, with a galvanometer, or current measure, to prove its existence. A is a bobbin of insulated copper wire, having attached to its ends, or in

circuit, a common galvanometer, B. When a permanent steel bar magnet, C, is quickly passed into the coil by the central aperture, a current is caused to circulate in the wire, and its direction will be indicated by the direction in which the galvanometer needle moves. This current is, however, only momentary, that is, it lasts just as long as the magnet is in motion within the coil, and ceases as soon as the motion ceases. If, however, the magnet is now withdrawn, *another* current will be caused to circulate in the coil, and its direction will be opposite to that of the first. This will be shown by the needle of the galvanometer, B, being deflected to the left.

This simple experiment contains the first of all the laws of magneto-electric induction, and is, in fact, the fundamental principle of every dynamo-electric machine.

Were it possible or practicable to make the magnet move backwards and forwards within the coil rapidly by means of any mechanical contrivance, we should have a magneto-electric machine on a small scale. The currents would be alternating in direction, just like those from the machine now used to burn the "electric candles," and would be induced in the coil just as long as the motion was kept up. Again, were it possible to cause an endless magnet to move in one direction in the coil continuously, we should have a machine yielding a constant current of electricity in one direction only.

The necessary materials for the practical illustration of this important principle may consist of a paper bobbin 3 inches long, wound with five layers of No. 22 B. W. G. cotton- or silk-covered copper wire; a galvanometer, or current detector, composed of a magnetised sewing-needle, suspended at its centre by a thread, within an oblong coil (say ten turns) of the wire. The needle must, of course, be held parallel with the wire coil. A steel bar magnet of the common kind, and 8 inches long, will complete the apparatus practically as exhibited in Fig. 17.

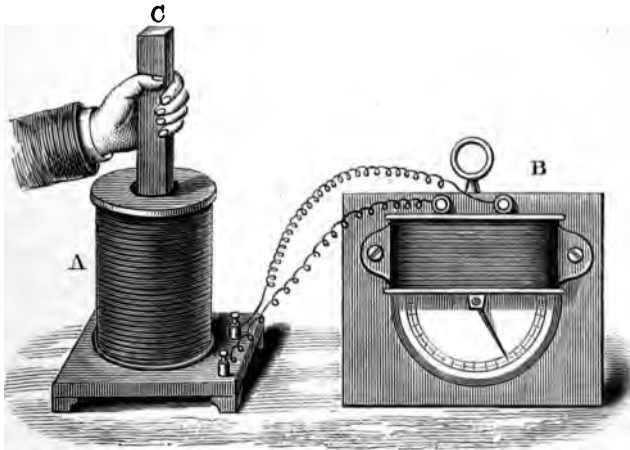


Fig. 17.—Faraday's Experiment.

This is called *magneto-electric induction*. It is more difficult to move the magnet in the coil when the circuit is closed than when it is open. The action that takes place may perhaps be explained as follows:—The movement of the magnet

induces a current in the coil, forming it into a magnet with its poles in a position such as to attract the poles of the moving magnet in the reverse direction to that they are moving in, and thus opposing the motion of the magnet. This opposition has to be overcome by force, and the energy thus expended, less that dissipated in heat, reappears in the form of current in the coil circuit. The magnetism thus forms a connecting link between the movement of the magnet and the current produced.

Fig. 18 illustrates an experiment in another kind of induction—*current* induction. Some electric

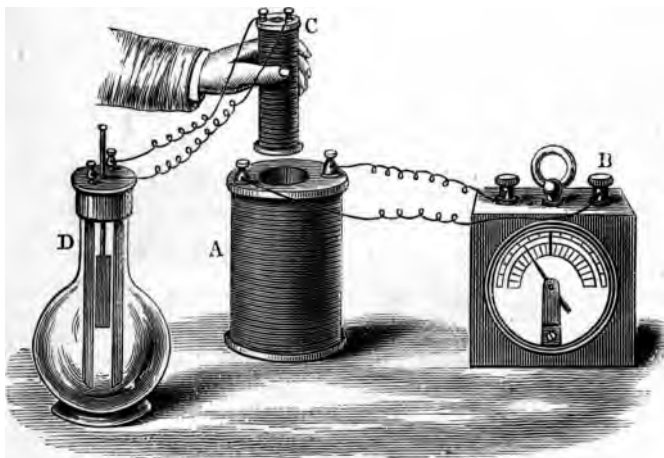


Fig. 18.—Induction Experiment.

generators have been constructed upon this principle; they are not the most successful, but it is important that the reader should understand, as

bearing upon the whole art of dynamo-electric machine construction, that a bobbin A, coiled with wire and connected to a current detector B, has induced in it currents in opposite directions as the wire bobbin C, drawing current from the voltaic cell D, is moved up and down in it. The principle is identical with that shown by the first experiment, the connecting link between the energy and the current produced being, in this case, not magnetism but electricity itself. All that can be done by the magnet may be done with the current bobbin C.

The materials to illustrate practically this second phase of the first law may consist of the same larger bobbin and galvanometer, with a ruler, coiled with two layers of No. 22 wire, connected to one of the bichromate of potash cells already mentioned.

First Magneto-Electric Machine.—A year after the publication of Faraday's experiment, a magneto-electric machine was brought out by Pixii, who caused the magnet to revolve its poles near to the iron cores of a pair of bobbins forming an electro-magnet. He, in fact, caused by mechanical means a permanent magnet to induce currents in the wire of an electro-magnet.

It comes to exactly the same end, whether the electro or permanent magnet is moved. Saxton, in 1833, improved the arrangement: he placed the whole apparatus horizontal, fixed the compound horse-shoe magnet, and rotated the armature in front.

E. M. Clarke, in 1836, designed the construction exhibited in Fig. 19. He placed the magnet vertically and revolved the coils about a horizontal

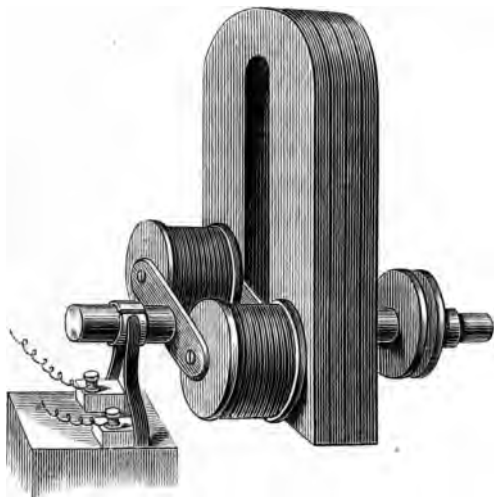


Fig. 19.—Clarke's Machine.

axis, and added a commutator to make the currents flow in one direction, which the author has endeavoured to make plain in Figs. 20, 21.

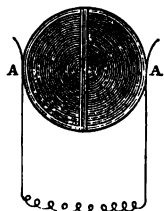


Fig. 20.—Commutator: End.

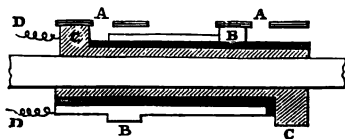


Fig. 21.—Commutator: Section.

In Fig. 20 are shown the two halves of a metallic cylinder, insulated from each other by some non-

conducting material as shown. A A are two contact springs for collecting the currents. Let us suppose that a constant current is being supplied to the two halves of the cylinder: in this case, as long as the cylinder remains in the position shown a direct current will pass to the springs, but if the cylinder is turned halfway round, the current will flow in the opposite direction in the springs, because the ends of the circuit connected to the cylinder remain the same, and communicate now with reverse springs. This is supposing a current in one direction, and as long as the cylinder rotates, the current will be reversed at each half-turn. The machine Fig. 19, however, gives alternating currents to the cylinder, and as these currents change direction just at the point where the commutator reverses, it is obvious that the alternating currents will now be made to flow in the springs always in one direction.

In practice, the common commutators are made like B and C, Fig. 22, which shows Stöhrer's machine of 1836. B is a cylinder, an explanation of the construction of which is given in Fig. 21, and C is a pair of contact forked springs. A and A in Fig. 21 represent the ends of the pair of springs C, just spoken of, and the cylinder is made up as shown in section. There are two metal tubes on the spindle, and they are insulated from each other by a tube of ebonite or wood, shown black. The metal tubes are connected to the wire coils as shown. B and C are projections on these tubes. They extend half round the circle, B and C (bottom) on one side,

and B and C (top) on the other. At each half revolution, therefore, as the coil changes the direction of its current, so do the cylinder and springs, the result being a constant current in one direction.

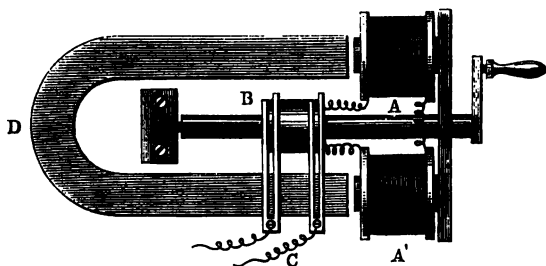


Fig. 22.—Stöhrer's Machine.

The current is strongest, of course, just as the coils, with their iron cores, pass the poles. In these machines, therefore, we have simply an electro-magnet revolved before the poles of a permanent magnet.

Clarke's machines are usually employed for "shocking" or medical purposes, and as no shocks would be felt upon grasping handles fixed to the wire ends were the currents continuous, it is usual to arrange an interrupter in the circuit. This may be done either by employing a third spring, working on a brass tube split, so as to give a break of circuit, at its centre, or by making the half-rings in Fig. 21 overlap on the tube—that is, making them slightly pass the central line. The result will be that the current at each half-turn will pass for an instant by the fork of the spring, so cutting it for

the same period of time from the exterior portion of the circuit.

Concerning the practical construction of these machines, it is not the author's intention to dwell upon it at great length, on account of their simplicity. It will, however, be useful to state that the iron used in these revolving electro-magnets, as *cores* and *yokes*, should be as soft and pure as possible, so that it may with rapidity change its magnetical polarity. Hard iron will develop only weak currents. The material usually employed is Swedish iron, made soft by soaking in a blood-red fire for some hours, and then cooling very slowly by burying in the hot ashes or allowing the fire to go out. The parts of iron to be screwed together must be quite clean, and in order to secure a good connection they should be quite flat.

The size and number of layers of *wire* must be regulated by the purpose for which the machine is intended. If high electro-motive force be required, as for an electro-medical machine, the wire should be fine, to give a great number of turns; but if the currents are required to do work in an external circuit of low resistance, a thick wire is to be employed. The electro-motive force and resistance of that part of the circuit formed by the moving coil will depend upon the number of turns of the wire, and upon its size. The greater the number of turns, the higher the electro-motive force, and the stouter the wire, the less the resistance.

The amount of current or quantity passing in a

given time in the circuit depends on the resistance of the whole circuit, as well as on the electro-motive force; and, therefore, if the portion of the circuit external to the machine is of small resistance the wire of the coils should be large, and if the external circuit is of great resistance the wire should be small and have many turns.

The principle is to some extent analogous to that of the voltaic battery, for when the cells are increased in size the internal resistance of the battery is decreased, and if the external resistance is small, the decrease in the total resistance of the circuit thus obtained more than counterbalances any decrease in electro-motive force. If the number of elements is increased the electro-motive force is increased, and if the external resistance is great compared to that of the battery, this more than counterbalances the increase of the battery resistance.

It is important that this should be borne in mind as bearing on the voltaic arc. Great electro-motive force will give a longer arc than a small electro-motive force; but if we get very small internal resistance we can produce with a given electro-motive force an arc which, though having a very small length, may, from the magnitude of the current passing, have a greater volume of light than with the greater length of arc. The exact relation, however, between all these elements of the question are not as yet entirely understood. Despretz, in a paper communicated to the French Academy,

published in the *Comptes-Rendus* of 1850, describes some experiments on the subject. He found that the length of arc increased more rapidly than the number of elements in series, and that by coupling given groups of batteries in parallel circuits (or, as it sometimes is termed, for quantity) very small arcs as regards length were obtained, but the amount of light given is not stated.

For medical machines, from No. 18 to 32 wire, cotton- or silk-covered, will answer, according to the tension required. No. 22 or 24 will usually be found suitable, and as many as from five to ten layers may be wound on the reels. All connections must be soldered to prevent bad contact, and care is necessary that the wire passes from one reel to the other like the letter S (A, Fig. 25),

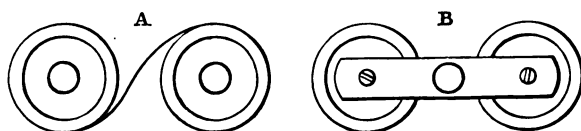


Fig. 23.—Electro-Magnet.

so that, in appearance, the winding may be in opposite directions. B, Fig. 23, exhibits the iron back and the coils.

Magnets of the permanent kind for such machines must be of good steel only. It is, indeed, imperative that the steel should be of the finest kind if the best effects are sought, and if it is required that the magnet should retain its force for many years. Steel of indifferent quality will soon become weak in magnetism.

The soft steel should be heated to a dull red, and then curved into the horse-shoe shape required. It should then be finished up, and again heated to a blood-red and plunged, bend first, in cold water or oil. This should make it so hard that a file will not act upon it, when it is ready for magnetisation. In order that the steel may absorb the maximum of magnetisation, it is usual to reduce its hardness at this stage to a slight degree by plunging it in a bath of melted lead or tin, the temper being observed by the colour produced. The steel may be magnetised by a permanent or electro-magnet larger than the new one, or by a few cells of the strong batteries, such as the bichromate or Bunsen. In magnetising by battery, the legs must be coiled with insulated wire. Four layers of No. 16 will be sufficient on each, and one minute of passing the current will suffice. The circuit should be broken two or three times during the operation. The process of magnetising by a magnet is by rubbing it upon the steel, pole following pole, from end to end, in one direction. A piece of soft iron must cross the poles of such magnets when not in use or while being magnetised.

Large Magneto-Electric Machines.

Some eighteen years passed without any great advance being made in the use of magneto machines, or any increase in their size, although several patents were taken out, some of which we shall have to allude to farther on.

The "Alliance" Machine.

In 1850 Professor Nollet, of the Military School of Brussels, commenced the design of a powerful magneto-electric machine, with the view of decomposing water and procuring oxygen and hydrogen for the lime light. In 1853 a company for this purpose was formed in Paris called the Société Générale de l'Electricité, and a large machine by Nollet was experimented on in Paris. The experiments failed as regards the lime light, but experiments on the electric light made by Mr. F. H. Holmes with this machine, altered to a continuous current machine by means of a commutator, were so far successful as to lead to further experiments both in France and England. About 1859 the Compagnie de l'Alliance was formed for the manufacture of electric light machines. In the machines made by this company the commutator of Holmes was removed and the alternate current again adopted, and the machine was known as the "Alliance Machine," Fig. 24. Mr. Van Malderon had much to do with the success of these machines, which were used afterwards in the French light-houses. From what was known when this machine was invented it was not possible, perhaps, to produce a better magneto-electric generator.

To a central shaft is made fast a series of copper or bronze discs, carrying each at its outer edges as many as 16 coils of wire with iron cores. The whole of this system, which may consist of as

many discs as may be required, is caused to revolve by attaching the central shaft to a steam-engine. To an outside frame is secured a number of compound steel magnets: 8 sets of magnets are provided, and the coils revolve between each pair of magnet poles. The actual construction has been varied many times; and not only for this reason, but because the author does not consider the

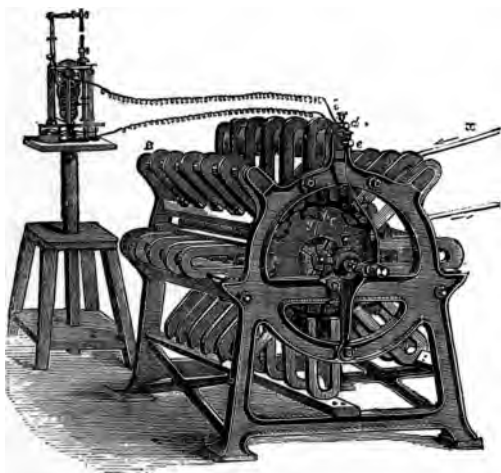


Fig. 24.—The Alliance Magneto-Electric Machine.

matter of sufficient importance on account of recent advances, no detailed account will be given.

The currents given off are collected, one sign from the axis and the other from a brass ring upon, and insulated from, the axis. Alternate currents are of course produced, and as there are as many changes of direction as coils, the machine gives 16 alternate currents per minute; the shaft being

driven at 400 revolutions, there must be at least 6,000 to 7,000 alternate impulses and changes of direction per minute.

As a matter of course, the parts, on account of these rapid magnetic reversals, become heated, but the way in which the parts are arranged causes them to act as a wind fan, which although it absorbs some power, keeps the machine cool enough for continuous working.

It was a modification of this class of machine which first illuminated the south lighthouse at Cape La Hève, in 1863, and the same apparatus, slightly improved, was put down at the north lighthouse in 1865. Two 8 horse-power steam-engines drive a pair of the machines at each lighthouse. The light from one is equivalent to 1,900 candles. The same kind of machine is fixed at Cape Gris-nez.

The Holmes Permanent Magnet Machines.

Mr. Holmes gave further attention to the subject, and in 1857 a large machine, made under his superintendence for the Trinity Board, was experimented on at Blackwall under the direction of Professor Faraday. In this machine the magnets, 36 in number, mounted on six wheels, rotated, and the coils were fixed and arranged in 5 rings of 24 each. Direct currents were produced by means of a commutator.

The experiments were satisfactory, and two larger machines were made for the South Foreland lighthouse. In these machines the magnets were fixed

and the coils rotated as in the earlier Alliance machine. The machine contained 60 compound horse-shoe magnets mounted radially in their vertical planes, the poles of the magnets being turned away from the centre. The coils, 160 in number, were mounted on two wheels about 9 feet diameter, 80 to each wheel. By means of a commutator direct currents were obtained. The power absorbed was $2\frac{3}{4}$ horse-power to each machine. On the 8th of December, 1858, the electric light produced from permanent magnets was shown on the sea for the first time at the South Foreland high lighthouse. These machines were afterwards removed from the South Foreland lighthouse and placed in Dungeness lighthouse, where the light was exhibited in February, 1862. Another machine was made by Holmes in 1867, afterwards used at Soutar Point lighthouse in 1871, in which the magnets were fixed, but turned with their poles towards the centre. There were in this machine 7 rings of 8 magnets each, and between the rings of magnets revolved 6 wheels on the shaft, having 16 coils each. This machine had no commutator, and the alternate currents were taken off by brushes. It is, in fact, nearly a return to the Alliance machine, viz. permanent magnets, horse-shoe magnets turned with their poles towards the shaft, the coils revolving, and no commutator. Professor Holmes afterwards designed other machines which do not belong to the permanent magnet class, and will be described farther on.

The Siemens' Armature.

In 1856 Dr. C. W. Siemens patented an armature of great merit for magneto-electric machines, and which has been, and is still, extensively used in magneto machines of various descriptions. It consists of a long iron bar, deeply grooved on two opposite sides, lengthwise. In this deep channel the wire is wound lengthwise of the bar, over its ends and along its sides. One end of the wire is soldered to the iron armature itself, and the other to a metal ring (insulated) on the driving spindle. This arrangement occupies the place of the electro-magnet in Clarke's machine, and it is rotated, by suitable means, *between* the poles of a powerful permanent magnet.

Fig. 25, which will further explain this, exhibits a cross section of the armature, with the wire in position. The sides of the armature are solid and rounded. Two cheeks, hollowed out, are shown attached to the poles of the magnet. These embrace the armature, which revolves very closely to them. It is usual in practice to wind the wire until it nearly completes the circular form of the sides. Rings of brass are then put over all, to prevent the wire from being forced out of position by the force of rotation. The pole cheeks are long, to embrace a considerable length of armature. There is very little churning of the air, as in Clarke's machines.

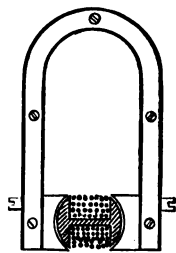


Fig. 25.—Siemens' Armature.

This form of Siemens' armature has been employed by Dr. Siemens in a magneto-electric machine, with a number of magnets arranged parallel to one another, and by several other makers, among whom may be mentioned Mr. Wilde, of Manchester, and Mr. Ladd, of London.

The armature, and several modifications of it, have been employed in magneto-electric telegraphic machines, and in the better class of medical apparatus. These forms of the machine do not, however, concern us here, although they are, historically, of much interest.

Pacinotti's Ring.

In the year 1860 Dr. Pacinotti devised a magneto-electric armature of peculiar form. It was first used in a machine made for the Physical Cabinet of the University of Pisa in that year. It does not appear, however, that Dr. Pacinotti published a description of his machine until the year 1864. The nature of the Pacinotti ring, as it is sometimes called, will be most readily understood by the description of Gramme's machine, to be given further on.

Breguet's Machine.

M. Breguet, a well-known manufacturer of electrical apparatus in Paris, constructs a machine which is composed of a pair of large permanent steel magnets, passing between the poles of which is a shaft carrying a stout iron disc, upon the face of which is secured, at right angles to it, a series of

iron cores wound with wire. These cores are so arranged that both magnets act upon them, one magnet upon their free ends, and the other upon the ends fixed to the iron disc.

The apparatus is simply an extension of Clarke's principle, but the number of bobbins admits of a continuous current being given off. The coils are joined up as a battery in series. As the system is caused to revolve, all the bobbins on one side of the poles will give off direct currents, while those on the opposite side will give off inverse currents. These currents are properly collected by a pair of springs at the changing or neutral line. The contact slips are disposed readily from the central parts of the disc, and to each strip are joined the two adjacent ends of each pair of coils.

There is no actual break of circuit during the revolution, because the contact springs are always bearing upon two or more of the radial slips.

On a large scale the machine would doubtlessly work very well, and is adapted for the rapid dissipation of heat generated by the magnetic reversals. But the same advantage is again a disadvantage, because the coils, being some way from the axis, act as a fan, and so consume power in churning the air.

C. F. Varley's Machines.

In the machines constructed upon the designs of Mr. C. F. Varley, actual, or nearly actual, contact is maintained between the armatures and the poles of

the inducing magnets. The magnets themselves, together with the intermediate cores, surrounded by coils of wire, form a complete ring, link, or circuit of iron, or iron and steel. These permanent or inducing electro-magnets have their respective north and south poles continuously or nearly continuously closed, notwithstanding the movement of the armature or armatures; but the armatures, when rotated or moved to and fro along the iron or link, affect the direction of the currents.

In arranging a machine on these principles in the simplest and most elementary form, two horse-

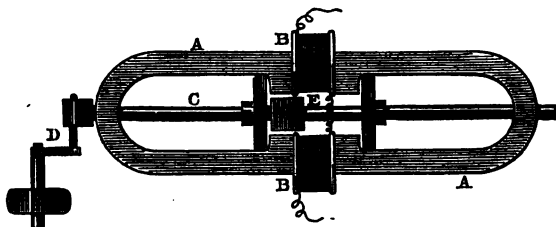


Fig. 26.—Varley's Machine.

shoe magnets are placed opposite to each other, and between their poles are two soft-iron cores, on which are wound coils of insulated wire. The poles of the magnets are placed, the north opposite the south. Together with these, which are the fixed parts of the apparatus (Fig. 26, A, B), an armature is employed, E, to which a reciprocating motion is given, which places it first in contact, or nearly so, with the two poles of one magnet, and then transfers it to a corresponding position with respect to the other magnet. The faces of the magnets and

of the armature may be grooved to increase the area of the surfaces in contact or in close proximity.

In place of a reciprocating armature, a rotating one may be employed, so formed as to connect the north pole of one magnet with the south pole of the other, and, as it rotates, to couple the poles alternately.

In the figure a shaft is shown, C, reciprocally moved by the crank and power pulley, D. In addition to this design of a dynamo-electric machine, Mr. Varley has invented various other pieces of apparatus for the production of single or multiple circuits of current.

M. Gramme's Magneto-Electric Machines.

M. Gramme, of Paris, introduced about the year 1871 what was considered at the time as an entirely new kind of armature, but which was afterwards discovered to have been invented previously by Pacinotti, as before alluded to.

It is a *complete ring of iron*, and the wire is wound upon it without a break all round the circle. If an iron ring has thus wound upon it an insulated wire, forming a complete coil, the ends of which are connected by soldering together, and if this coil and ring are caused to rotate upon a central axis between the poles of a magnet, there will be developed in the coils a curious electric state. Two currents are constantly flowing in the wire, such that as each point in the circuit arrives at a spot

equidistant from the two poles of the magnet, that point in the wire has a maximum positive potential, whilst the point in the coil exactly opposite to this has a maximum negative potential. If now the exterior turns of the wire are denuded of covering, and a pair of springs made to press, one on each side of the ring, on a line directly between the poles, a constant current, similar to a constant fall of water, will pass in any outside circuit connected to the springs.

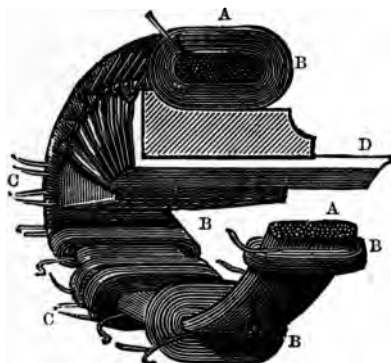


Fig. 27.—Gramme's Ring.

A Gramme ring may be made to work just as described, but in practice a different way of constructing the ring is adopted.

M. Gramme makes his ring armature up as shown in Fig. 27, where A and A are the ends of a coil or ring, composed of a great number of soft iron wires.

B B B are the coils of wire used by M. Gramme to cover the ring, it being found more convenient

to make up the endless coil in sections, and then join them properly together, than to wind the wire from end to end and take the currents from the bared exterior. The upper part of the ring is seen fully coiled, while the lower side is being filled with coils. C C are the ends of the coils of wire, which are taken out for connecting up after the ring is complete. At D is shown a number of copper plates radiating from the centre, and having fixed to them, in notches and with soldering, the ends of the completed coils of wire. These radiating plates are simply for the purpose of carrying the currents along the wooden axis to the point where they are taken off by a pair of contact pads or springs.

When the ring is complete, it is entirely covered with coils of insulated wire, and each coil is connected to a copper plate. The connection is made up, however, in this way:—No. 1 coil has its inside end connected to No. 1 copper plate, and to the same plate is connected the outside or commencing end of No. 2 coil. The other end of No. 2 coil is then connected to No. 2 plate, and to the same plate is joined the outside end of No. 3 coil. This is continued around the circle, and the plates act exactly as if the wire was simply bared, and the currents collected direct. These radiating copper plates are also exhibited in the following views of the machine and its parts. The centre of the ring is filled up with a block of wood, through which runs the central spindle, and into slits in which the copper plates fit. In Gramme's ring

the iron wires forming it are not divided as represented in the figure. They form an endless hoop of soft iron, enveloped in an endless helix of insulated wire.

The length of wire in each coil will depend upon the size of the machine and upon the size of the wire. For No. 12 wire, well insulated, as much as 12 yards may be placed in each coil, and it is important that those coils are not very thick. They

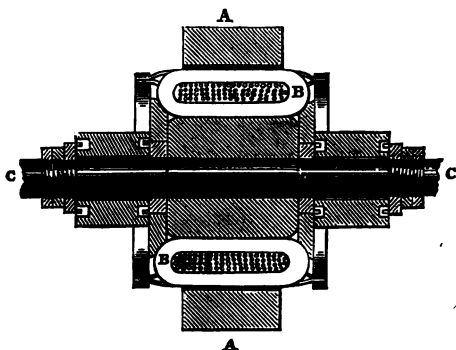


Fig. 28.—Section of Gramme's Ring.

should be so thin as to allow about fifty to be placed on a 5-inch ring; but a great deal will depend upon the amount of care employed. Every part of the ring must be covered, and it will be found best, as convenient in making up the central space equal to the exterior, to coat the copper plates with gutta-percha and varnish at their outer edges, and to place them between the coils against the ring itself. Fuller particulars for actual construction will, however, be found further on.

Fig. 28 exhibits a section of the wire ring and

coils, B B, upon a central spindle, C C. A A are the magnetic pole-pieces between which the ring revolves. It will be observed that there are lock-nuts to secure the central portion in position.

Gramme's magneto-electric machines are now

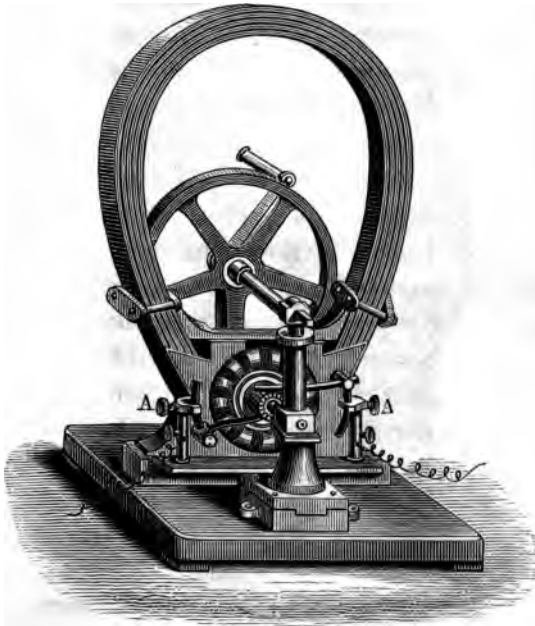


Fig. 29.—Gramme Hand Magneto-Electric Machine.

manufactured by M. Breguet, Boulevard Mont-Parnasse, 81, Paris, in two or three forms to suit hand-power. The machines are very useful in laboratories, where a powerful current of electricity is often required. The best type are those with Jamin's laminated magnets.

Fig. 29 is a view of this machine. It will be observed that, as in many other forms of the

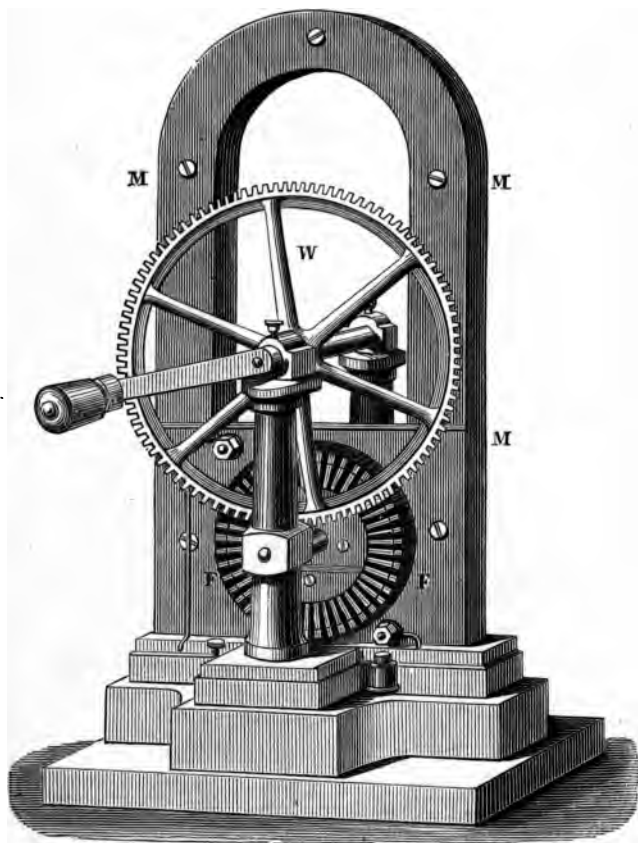


Fig. 30.—Gramme Hand Magneto-Electric Machine.

Gramme machine, the currents are collected upon the *neutral magnetic line*, that is, on a line passing *between* the poles of the magnet, vertically.

The following are a few instructions by which the amateur may be enabled to make for himself a very useful hand magneto-electric machine. The construction is not difficult, and doubtlessly will be undertaken by very many in want of some clean and handy apparatus to supersede the troublesome and often unwholesome battery.

Fig. 30 represents a more simple form of the same machine, in which the magnet is composed of four or five sections, forming a compound magnet of considerable power.

The magnet is a permanent steel one. Some idea of the effect obtainable from the current, while the hand-wheel is driven at about 80 turns per minute, may be gathered from the fact that 14 in. of No. 36 B. W. G. platinum wire is brought to a white, glowing heat in a few seconds, and the turning of the handle at a fairly uniform speed may be easily kept up for almost any time required in ordinary experiments.

The general arrangement of the parts is indicated by the figure, in which M M is the permanent magnet, w the driving-wheel, gearing in a pinion on the spindle of the Gramme ring. Screws are represented on the face of the magnet. These are employed when the magnet is made of two or more sections or layers of steel. A solid steel magnet is used in the machine made by M. Breguet, but it is undoubtedly better to make it up from two or more layers, although in this case constructional difficulties are much augmented. The teeth of M.

Breguet's driving-wheel are cut obliquely upon the circumference of the wheel. This is supposed to both decrease the noise and the risk of breakage; but the common wheel and pinion will be found to work the ring quite well. The base is solid, and it is imperative that it should be of some heavy non-magnetic substance, if the machine cannot be clamped or screwed to a table; this insures steadiness. The bearings or standards for the driving-wheel spindle also carry the ring spindle, and are of gun-metal. The driving-wheel may be of brass, as, although cast-iron would do, it is very apt to give way at the toothed portion; brass or gun-metal is, therefore, to be recommended. The magnet should be of the best steel only, because steel of indifferent quality will not only fail to take up sufficient magnetism, but will lose its little strength in course of time. Even the best steel will, in a few years, lose some of its magnetic strength, but it is no difficult matter to re-magnetise it. The wire used in the construction of the ring should be of the softest iron procurable, and the wire from which the coils are made should be of good copper of high conductivity. A high degree of accuracy is not necessary except in the making up of the ring, which must be truly circular and somewhat equally weighted.

Construction: the Magnet.—This part of the machine may be constructed in more ways than one. What is really required is a concentration of magnetic power at the ring-cheeks, *p p*, Fig. 31.

Various forms of magnet might be employed to effect this, exclusive of electro-magnets; but as space in height is of little moment, and as the steel is most conveniently arranged vertically, the form of magnetic arrangement exhibited by Fig. 31 will be found to answer the purposes of the amateur best.

Fig. 31 represents the magnetic horse-shoe $M M$; the concaved cheeks, $p p$, may form part of the same mass of metal, but it will be found most easy in practice to make them of cast-iron, and to screw them to the magnet limbs as shown at the dotted lines on either side. The feet or basis of the bent bar should be attached by screws from underneath, on account of the

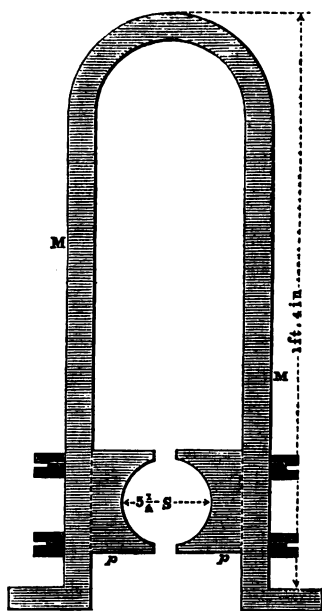


Fig. 31.—Small Gramme Magnet.

difficulty of placing wire coils upon the magnet in the process of imparting the necessary magnetic strength. The length of the bar complete may be 3 ft., its width 3 in., and its thickness $\frac{1}{2}$ in. It should be made from rolled steel, of flat bar shape, although any other shape of steel will answer the

purpose. It is well to know, however, that if the thickness be greater than $\frac{1}{2}$ in., the extra metal will be superfluous, for thick bars do not carry more magnetism than thin ones, and the difficulty of hardening will be greatly increased.

The bar should first be bent to a U-shape, with two limbs of equal length, and a space between them of $6\frac{1}{4}$ in. It may then be finished up, and have the screw holes for the cheeks and feet drilled. The screws may be ordinary $\frac{3}{8}$ -in. bolts or screws. The hardening and tempering should then be proceeded with. The bar should be hardened in a good charcoal fire, which must be of equal heat throughout the space occupied by the steel. As soon as a good blood-red heat is attained, plunge it into water, *bend first*, vertically. If this is not done as directed, it is probable that the bend will be softer than the other parts. The steel should be so hard that a file will scarcely cut it. Leave the "skin" on, and coat with sealing-wax or other varnish, except where the cheeks, *p p*, are to bear. If the magnet is to be magnetised by rubbing with another, do not yet coat with varnish.

Magnetism may be obtained in two ways: these are, first, by rubbing with a sufficiently strong electro-magnet; second, by passing round the steel a strong current of electricity. Very few people possess electro-magnets of sufficient strength to impart much vitality to so large a mass of steel, so that it will be best in most cases to use the voltaic current. It will be necessary to place upon the

steel legs a pair of long coils of stout cotton-covered wire. No. 16 B. W. G. wire will answer very well, and as many as four layers ought to be in each coil, if its length does not cover the straight part of the steel. The battery power to employ may consist of just as many quart Bunsen's or bichromate cells over 6 as the maker may possess. The more battery power the more magnetism, usually up to 20 cells. Ten cells of the simple bichromate battery in series will answer very well. The current may be passed for about a minute, and the circuit should be broken several times during this minute. The bar will be more difficult to magnetise, as it is harder; but the magnetism will last longer without variation. The poles should be crossed by a piece of iron during magnetism. Care should be taken that the wire from one leg crosses to the other like the letter S; if this is not attended to, and the wire is not wound as it is upon common electro-magnets, the magnetisation will be a failure and must be repeated under different conditions. If the wire be coiled upon the steel direct, it will be safest for the amateur to continue the coiling over the bend, when the direction must be correct.

The cheeks *p p* are of cast-iron. They should be 6 in. high by 5 in. wide, and thick enough to allow of the $5\frac{1}{4}$ -in. circle, S, being cut from them. The space between their faces will thus be about half an inch or more. It will be best to have them cast to pattern, and then turned out. If there is con-

venience for annealing the cast-iron, this may be done in a charcoal fire by heating to redness and cooling slowly. The circular space, S, should be as true as possible, for it is upon the nearness of the iron to the ring that the effects, to a great extent, depend. The backs must be made flat, to bear truly upon the clean flat surface of the magnet itself.

If the base is to be of iron, and the feet of the magnet are to be secured to it direct, they must be of brass, and brass screws must be used. If a wooden base is to be employed, the feet and screws may be of any metal. It will thus be seen that care is necessary not to close the magnetic circuit of the horse-shoe by any iron prolongations. The magnetic arrangement must be made steadily fast to the base, in position, and the rest of the work may be proceeded with.

The Ring, or Armature.—In the Gramme machine, the best form of ring consists of a flat bundle of soft iron wires, as is exhibited by Fig. 27, p. 76. The bundle of wires is a little more difficult to arrange in practice than one ring of iron. A good plan is to make it up of three 2-in. wide lengths of soft iron, one over the other. The innermost layer must be shorter than the second layer, and it must, in turn, be shorter than the outside layer. They are to form an almost complete ring, except a gap of $1\frac{1}{2}$ inch wide, to allow the coils of wire, B, to be slipped on. This gap, when all the ring is coiled, is then to be filled up with a piece of iron

having a coil of wire upon it. This will complete the ring, the iron body of which must be continuous. The diameter of the ring, *outside*, is to be $3\frac{1}{2}$ in., and its diameter inside will thus be about $2\frac{3}{4}$ in., its width will be 2 in., and this size of ring will, when coiled with wire, give an outside ring of 5 in. diameter or a little over, to fill the space S, Fig. 31, with clearance room.

The coils of wire, B B, Fig. 27, p. 76, are to consist of four layers of No. 16, silk- or cotton-covered. Silk will prove the better insulator, but cotton will answer, if well dried and soaked in melted solid paraffin. The layers of wire are to be $1\frac{1}{2}$ inch or rather less in width. They should be first coiled upon a former, or mandrel, having the same size as the ring body, and may be kept in shape by tying with silk thread and steeping in paraffin. They are to be slipped on, entering at the gap A A, Fig. 27, p. 76, until the ring is quite full, and their ends, C C, are directed to one side. The last coil, filling up the gap in the ring, is to be placed upon the piece of iron filling up the gap. This iron piece should fit into the ends so as to *spring them apart*, and must have a catch or taper filed upon it to keep it in place when it is tightly pressed in. A ring made from a hoop of soft iron, solid, answers very well.

We have now the ring, with the wire upon it, and all the coil ends extending outwards at one side. There will be spaces at the outside not filled with wire, and they should be filled up completely with some such substance as melted pitch, to which some

gutta-percha has been added. Concerning this, it should be remarked that these spaces will not exist if the contact plates of copper (D, Fig. 27) are placed *within* the ring, as there shown. It will, however, be easier for the amateur to leave the ends as they are, and to proceed to finish the ring as follows:—Turn a box or hard-wood drum to fit the centre of the ring tightly. Let it be *very slightly* tapered and somewhat rough, to give a hold to the cement. Its length should be 7 in., and it should

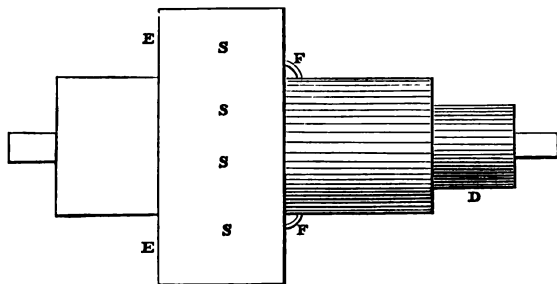


Fig. 32.—Gramme Ring and Contact Drum.

have a central aperture to receive a tightly driven spindle of $\frac{1}{2}$ -in. round iron, of length over all 9 in. Let the wooden drum pass through the ring until its thickest end is nearly flush with the wire coil and the small end projects considerably. Mark this place, remove the ring, and in the wooden drum—commencing at the mark reached by the coils—make a number of slots or cuts with a saw. These cuts must be equal in number to the coils, and must radiate from the centre. Fig. 32 is intended to represent this. Now turn down the wooden drum

for 2 in. at one end; reduce until the diameter is 1 in; D, Fig. 32, will now represent this end so reduced. The depth of slots will be reduced also.

Into these slots must fit tightly pieces of thick sheet copper, D, Fig. 27, p. 76. These radiating slips must be driven in, and their edges should be flush with the wood drum, both at the wide and reduced parts.

File the slips down to the cylindrical form, connect the coils with the slips, and, to fasten on the ring, press the ring firmly on the spindle or drum. Melt a quantity of pitch and a little gutta-percha together, and fill in between the ring and the drum with it while very hot. When this sets it will fix the ring in position. Bring out all the cleaned extremities of the coils, and commence by soldering the finishing or outside end of No. 1 coil to No. 1 copper slip; solder also to No. 1 slip the inside or beginning end of No. 2 coil. Solder the finishing end of this coil to No. 2 slip, and to the same slip the commencing or inside end of No. 3 coil. Continue thus until all the coils are connected to the copper slips, paint over with hot gutta-percha and pitch, and the ring with its connections is complete.

Fig. 32 will render the arrangement more clear, where E E represents the ring upon its axis, S S the coils, F F the ends of these joined to the copper slips, which lead along the drum, as the lines indicate, to D, which is the reduced end spoken of, with the slips having their edges flush with it.

Fig. 28, p. 78, will render the whole still more intelligible ; but there are joints shown here which are intended to represent the way in which Gramme mounts the ring upon its spindle.

The actual construction of the spindle and the mounting are ordinary mechanical operations. The toothed driving-wheel may conveniently have a diameter of 10 inches, and the pinion a diameter of $1\frac{1}{2}$ inches. The number of teeth is a matter of little consequence, but the pinion and wheel must agree as to *pitch* of the teeth, otherwise they will not run together. It will be found best to provide a gun-metal pinion, and to drive a pin right through its hub and the spindle. The height of the standards must be regulated accurately, to allow the 5-in. ring to revolve freely in the space S, Fig. 31. Nothing further should be done until this part is very exactly fixed in position. The distance between the centres of both spindles must be marked off on the uprights, and will always afterwards be correct. The lower spindle must be so set that the ring occupies as nearly as possible the central portion of the cheeks *p p*, Fig. 31.

As to the side of the machine at which the reduced or "contact" end of the wood drum projects, it is of little consequence ; but it will be found most convenient to project it from the side opposite to the driving-wheel, because arrangements are to be fixed here for carrying a pair of contact springs for collecting the current from the copper slips, as they project at D, Fig. 32.

When the ring is caused to revolve without the contact brushes pressing upon the slips, there can be no circuit for currents, so that no currents are induced in the ring by the magnet.

Reference to Fig. 33 will render clear the manner in which the contact springs should be arranged. One presses upon the upper side of the drum end, and the other on the under side of the drum. The edges of the radiating slips being flush with the circumference, there is not a heavy contact, but it is

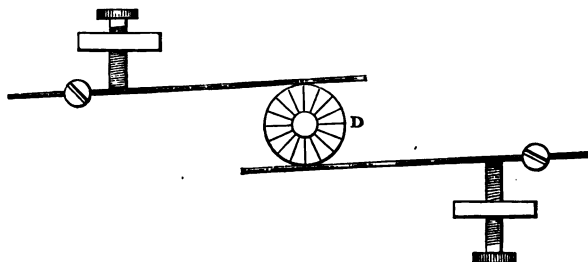


Fig. 33.—Contact Springs and Drum.

sufficient to collect the impulses as they are given off. These currents are constantly in one direction, and in this respect resemble a fall of water.

The springs represented at Fig. 33 are most conveniently made up from a number of stiff copper wires; but brass wires will answer, although they will be burned sooner if there is much sparking. The springs should be adjustable, through the screws fastening them, to expose fresh surface to the friction when necessary; and the thumb-screws shown serve to cause them to bear more or less

heavily upon the axis. This part must be oiled occasionally.

From these contact springs the wires are taken to the binding-screw exhibited in Fig. 29. Stout covered wires should be employed to connect the machine to any piece of apparatus. M. Breguet supplies with the machine two rings, with thick and fine wire, for currents of low and high electro-motive forces. The currents must always be collected upon or near the neutral line.

De Meritens' Machine.

The construction of this machine provides for the armature a wheel, with a rim composed of segments of soft iron, wound as usual with wire at right angles to the iron segments, which are separated magnetically by strips of copper. All the segments are wound in one direction, but the outside end of one coil is joined to the outside end of the next, and the inside end is joined to the inside of the preceding coil.

This ring-tire armature is made to revolve inside the poles of a number of permanent steel magnets, arranged around in a circle parallel to the shaft of the revolving wheel. There is thus a regular succession of poles in the ring—N.S.N.S.

By this arrangement of coils, and the size of the coils in relation to the distance between the magnets, as one coil is approaching a north pole the next is approaching a south pole. Currents in *opposite* direction in these two *coils* are therefore

produced, but by the mode of coupling the ends of the coils described above, these currents become in the *circuit* in the *same* direction. The current, however, is of course reversed, as any one magnet approaches and then recedes from any one pole, thus the machine produces currents which alternate in their direction.

The terminations of the wheel coils are soldered to a pair of brass or copper rings upon, and insulated from, the central spindle. From these rings the current is taken off by copper brushes, usually composed of springy wire of large size.

It has been found that this machine produces remarkably strong currents in comparison with other machines of the same type. Were the sections composing the circular armature not insulated magnetically from each other as they are, some comparison might be made with the Gramme magneto machine, for the currents are induced under similar conditions, except that De Meritens employs a number of small magnets.

CHAPTER V.

ELECTRO-MAGNETO ELECTRIC MACHINES.

HITHERTO we have only alluded to magneto-electric machines in which the current was produced by revolving coils of wire placed on soft iron cores, near fixed permanent magnets, or *vice versâ*, revolving permanent magnets near fixed coils. It will be evident, however, that electro-magnets excited by currents from some source of electricity may be substituted for fixed permanent magnets; and, in fact, in 1845 Professor Wheatstone patented the substitution of electro-magnets for permanent magnets in magneto-electric machines for telegraphic purposes, and in 1852 Watt, in a patent, mentions the same idea; but no particular use seems to have been made of these suggestions.

Wilde's First Machine.

In 1863 Mr. H. Wilde, of Manchester, took out a patent for a machine for obtaining electric currents in which a large electro-magnet was excited by means of a battery, or by the current from the armature of a small magneto-electric machine, both

machines having Siemens' armatures, a commutator being arranged on the small machine, so as to give a current in one direction round the electro-magnet of the large machine. Mr. H. Wilde constructed a large machine on this principle, and appears to have first brought the principle before the public in two papers, read at the Royal Society on April 26th, 1866. "1. On some new and paradoxical phenomena in electro-magnetic induction, and their relation to the principle of Conservation of Physical Force. 2. On a new and powerful Generator of Dynamic Electricity."

The machine described consisted of a small magneto-electric machine, in which the magnets were permanent magnets, and the armature a Siemens' armature, standing on a large magneto machine, in which the magnets were electro-magnets, these electro-magnets being excited by the current from the armature of the smaller machine. The current from the large armature was consequently very powerful.

Fig. 34 shows an end elevation of this machine. MM' is the small permanent magneto machine with its Siemens' armature C ; r and r' are the terminals connecting the commutator brushes of the small machine to the insulated copper bands of the large electro-magnet EE' . The wires Z and Z' show the external circuit connected to the contact brushes of the armature of the large electro-magnet.

Mr. Wilde carried his principle further, and made

and described a machine where the current from the

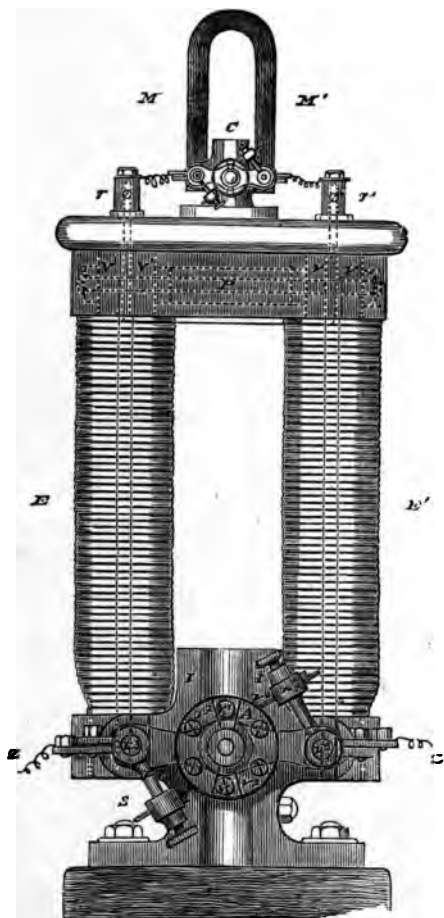


Fig. 34.—Wilde's Magneto-Electric Electro-Magneto Electric Machine.

first excited the electro-magnets of a second, and the current from the second excited the electro-

magnets of a third, the diameters of the Siemens' armatures being respectively $1\frac{5}{8}$ inches, 5 inches, and 10 inches.

The magnets of the small magneto-electric machine consist of six magnets weighing 1 lb. each, and the magnets of the 10-inch machine weighed 3 tons. The machine was furnished with two armatures, one for the production of "intensity," and the other for the production of "quantity," effects.

The intensity armature was coiled with a bundle of thirteen No. 11 copper wires 376 feet in length, and weighing 232 lbs.

The quantity armature was wound with copper plate 67 feet long, weighing 344 lbs.

The armatures were driven at the rate of 1,500 revolutions per minute.

When the large machine was excited by the medium, which in its turn was excited by the smallest machine, enormous effects were produced, and a piece of iron 15 inches in length, and $\frac{1}{4}$ of an inch in diameter, was melted. This was with the quantity armature. With the intensity armature the current produced melted 7 feet of No. 16 iron, and made a length of 21 feet red hot. The intensity armature was used for the electric light, with gas carbon $\frac{1}{2}$ inch square, and the light evolved was sufficient to cast a shadow from the flames of the street lamps a quarter of a mile distant.

In March, 1867, Mr. Wilde exhibited a large machine of this description at the conversazione

of the Royal Society at Burlington House. The electric light was shown in great splendour, and iron rods 15 inches long and $\frac{1}{4}$ inch in diameter were fused.

Wilde's Armature.—Although the distinctive features of Wilde's machine lie in its magnets and arrangement, the make of Siemens' armature adopted by him calls for further explanation.

Fig. 35 exhibits this construction. The metallic portion of the armature is shown in the end view with cross section lines and the wire wound upon it in three layers. This cast-iron body extends from A to A, and in its longitudinal side grooves the wire is wound. The length of covered copper wire wound on is about 50 feet, and after the wire is on, a wooden packing serves to keep it in place and make up the circular form of the armature. Straps of brass encircle the armature at different intervals along its length; this prevents the coils from being forced outwards by centrifugal force. These are sunk in grooves made for them in the cast-iron body and wooden pack-

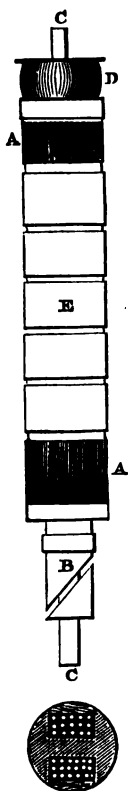


Fig. 35.

ing E. Two ends of brass are fitted to the ends of the armature, and to these brass caps are made fast the steel axis ends C C. D is the pulley by which motion is given to the armature from a strap.

The Commutator is of simple construction, and is shown at B. It is composed of two rings or sections of copper, fitted upon the steel shaft C, and insulated from each other. Upon this commutator or current reverser press the contact springs which take off the currents. One-half of the commutator is connected to the commencing end of the coil, and the other to the finishing end. As soon as the armature begins to move, a current begins to be induced in it, and for each revolution two opposed currents are given rise to in its coil. If the springs press upon the commutator, it will be seen, since the latter is separated by an oblique cut, that the springs must exchange parts at each half revolution, and as this exchange takes place at the moment when the armature reverses its current, the springs take off the current in one continuous direction.

CHAPTER VI.

DYNAMO-ELECTRIC MACHINES.

THE machine made by Mr. Wilde was an immense step in advance of all previous means of obtaining electricity from motive power, but a further step was very shortly to be made of still greater importance.

About the end of 1866, or beginning of 1867, the idea of employing the current, or a portion of the current, from an electro-magnetic electric machine to *excite the electro-magnets* themselves, thus dispensing with voltaic batteries or any primary exciting machine, occurred to Messrs. Varley, Siemens, and Wheatstone. Messrs. Alfred and Cornelius Varley patented this principle in 1866. In January, 1867, Dr. Werner Siemens communicated this principle to the Academy of Science at Berlin, and in February, 1867, Dr. W. Siemens communicated the same to the Royal Society. About the same time Professor Wheatstone published a similar idea. But all these gentlemen were, as far as printed publication went, long anticipated by Søren Hjørth, of Copenhagen, who in 1854 had patented this principle very distinctly, giving drawings in his specifications.

Mr. Murray also, in the *Engineer* of July 20, 1866, states that he, using only a single machine, passes the currents from its armatures through wires coiled round the permanent magnets in such a direction as to intensify their magnetism, which in its turn reacts upon the armatures and intensifies the current.

On February 14, 1867, two papers on this subject were read before the Royal Society. The first, received February 4, was "On the Conversion of Dynamical into Electrical Force without the aid of Permanent Magnetism," by C. W. Siemens, F.R.S.

The author says, "An experiment has been suggested to me by my brother, Dr. Werner Siemens, of Berlin, which proves that permanent magnetism is not requisite in order to convert *mechanical* into *electrical* force; and the result obtained by this experiment is remarkable, not only because it demonstrates this hitherto unrecognised fact, but also because it provides a simple means of producing very powerful electrical effect." After describing the principle of a dynamo machine, in which a single element of a battery was used to start the magnetism, he says, "The co-operation of the battery is only necessary for a moment of time after rotation has commenced, in order to introduce the magnetic action which will thereupon continue to accumulate without its aid. The mechanical arrangement best suited for the production of these currents is that originally proposed by Dr. Werner

Siemens in 1857 (see 'Du Moncel sur l'Electricité,' 1862, page 248), consisting of a cylindrical keeper hollowed at two sides for the reception of insulated wire wound longitudinally, which is made to rotate between the poles of a series of permanent magnets, which latter are at present replaced by electro-magnets.* On imparting rotation to the armature of such an arrangement, the mechanical resistance is found to increase rapidly to such an extent that either the driving strap commences to slip, or the insulated wires constituting the coils are heated to the extent of igniting their insulating silk covering.

"It is thus possible to produce mechanically the most powerful electrical or calorific effects without the aid of steel magnets."

The second paper, received February 14, was "On the Augmentation of the Power of a Magnet by the reaction thereon of currents induced by the Magnet itself," by Charles Wheatstone, F.R.S.

The author states, "In the present note I intend to show that an electro-magnet, if it possess at the commencement the slightest polarity, may become a powerful magnet by the gradually augmenting currents which itself originates." He then describes a machine the same as the electro-magnetic part of Mr. Wilde's machine, and then goes on to show that little effect is produced by temporarily exciting the electro-magnet if the circuits of the armature and magnet are separate. But if the

* It being understood that the current from the armature is by suitable commutator led round the electro-magnet coils.

wires of the two circuits (*i.e.* the electro-magnet and armature coils) be so joined as to form a single circuit, in which the currents generated by the armature, after being changed to the same direction, act so as to increase the existing polarity of the electro-magnet, very different results will be obtained. The force required to move the machine will be far greater, showing a great increase of magnetic power in the horse-shoe; and the existence of an energetic current in the wire is shown by its action on a galvanometer, by its heating 4 inches of platinum wire .0067 in. diameter, by its making a powerful electro-magnet, by its decomposing water and other tests.

The principle thus brought prominently forward by Dr. Siemens and Professor Wheatstone, and previously patented by Sören Hjorth and Messrs. Alfred and Cornelius Varley, and published by Murray, was soon brought to bear in the construction of an infinite variety of machines for obtaining electricity from mechanical motion without the aid of permanent magnets or batteries, and the name of dynamo-electric machine has been given to them in distinction from magneto-electric machines, where permanent magnets are employed. Dr. Siemens' machine, constructed to show the principle, consisted of flat electro-magnets like Wilde's, with the Siemens' armature, only the machine was laid horizontal instead of vertical.

Mr. Wilde soon adapted this principle of reaction to his machines, dispensing with the per-

manent magnets, but still using a small electro-magneto electric machine, as well as a large one, the current from the armature of the small machine being made to pass round the wire of both machines to excite their electro-magnets. The current from the armature of the large electro-magnets was used alone for external purposes.

As the heat is sometimes great, some of Wilde's machines have the central shaft hollow, and a current of cold water is caused to pass through it, and also through the tubular large electro-magnet.

These machines have had their chief application in electro-metallurgy, but they have also been used for the production of the electric light.

Ladd's Dynamo-Electric Machines.

Mr. Ladd, of London, made a machine, Fig. 36, which differed from Wilde's in having two flat

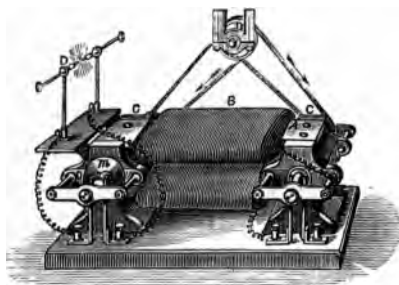


Fig. 35.—First Form of Ladd's Machine.

electro-magnets, B, placed parallel, with Siemens' armatures, C C, revolving at each end of the system, Fig. 36. The current from one of the armatures

excited the electro-magnets, and the current from the other was used for external purposes. Mr. Ladd also constructed the form of machine exhibited in

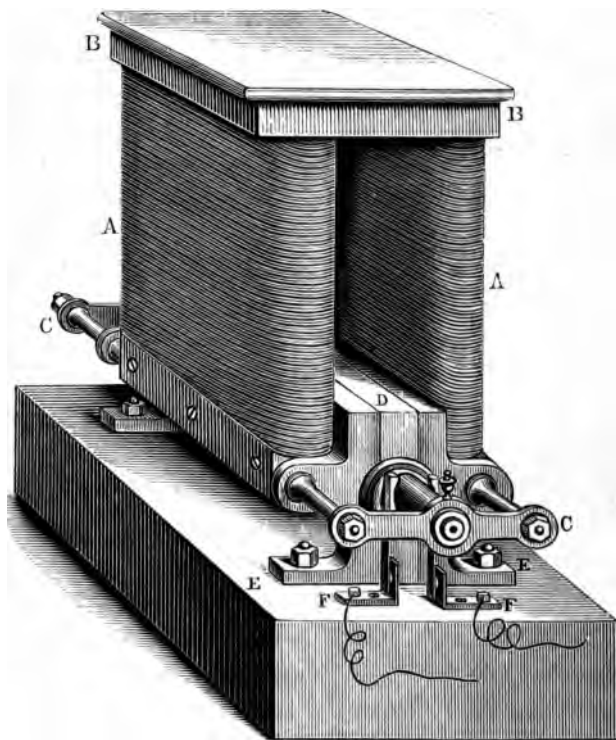


Fig. 37.—Ladd's Machine.

Fig. 37, with two armatures fastened upon one shaft; one armature is used to excite the electro-magnet and the other is reserved for outside work.

Holmes's Dynamo-Electric Machine.

In 1869 Professor Holmes made a dynamo-electric machine for the Trinity House. The machine consisted of ten electro-magnets fixed to a revolving shaft, the poles of the magnets, turned outwards from the shaft, passing as the shaft revolved by fixed coils. A part of the current from the coils was passed along the shaft to the coils of the electro-magnet. It was intended for use in the South Foreland, and gave 2,800 candle power, but was not used.

From this point the author does not pretend to give descriptions of the various machines in the order of the date of their invention.

Gramme's Dynamo-Electric Machine.

The Gramme magneto-electric machine has been described; the Gramme ring armature being the essential feature of the arrangement. In the Gramme dynamo-electric machine the ring is the same in principle and form, but the magnets are electro-magnets, formed by bars magnetically joined by the frame of the machine, and the insulated wire on them is wound in such a way that the mass of metal joined to the *centres of the bars*, or groups of bars, are the *magnetic poles* when the magnets are excited. The current from the coil is led through the electro-magnet coils as in most dynamo-electric machines.

Fig. 38 is a view of a complete Gramme machine of the smaller type. It is much used in electro-plating and in illuminating workshops. The illuminating power of the current it yields is about 2,000 candles. Its weight is 1 cwt. 2 qrs. The armature should make 1,600 revolutions per minute, with a horse-power of $1\frac{1}{2}$.

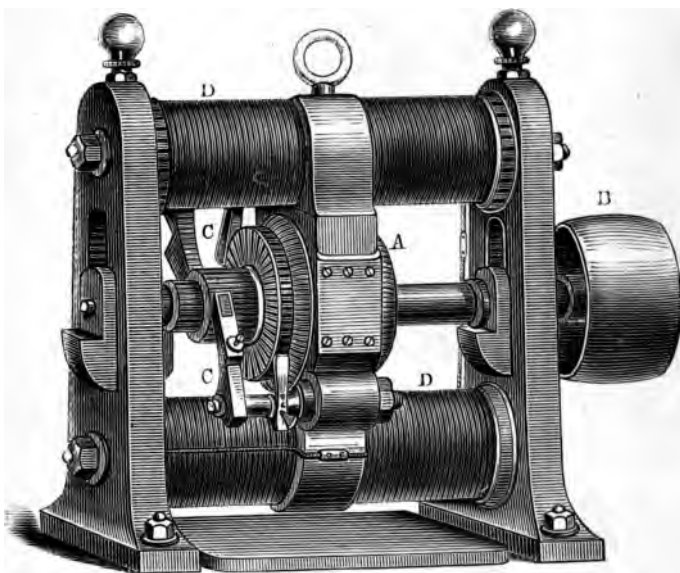


Fig. 38.—Small Gramme Machine.

DD are electro-magnets, connected through the framework, and this brings the poles to the cast-iron cheeks which embrace the ring above and below. The system composes, therefore, one electro-magnet. A is the ring, CC the collecting brushes, B the driving pulley. The height of this

machine, as shown, is 23 inches. Length 25 in., width, 13 in.

Fig. 39 is an end sectional view of a Gramme machine of a small size. A A' are bars, of the electro-magnets, wound with thick copper wire. These bars form the two poles of a magnet, as they are

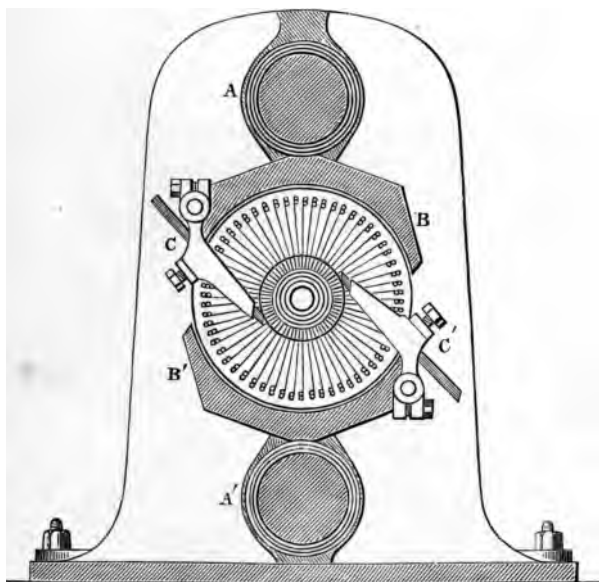


Fig. 39.—Gramme Machine : Section.

connected together at their ends, through the framework of the machine. B B' are the pole pieces, or cheeks, which embrace the ring for about seven-eighths of its circumference. The ring revolves very near to them. C C' are the collecting pads, brushes, or springs. These usually consist of a bundle of

hard copper slips, or hard copper wires, passed through, secured by, and regulated as to length through the holders shown. These brushes need attention about once a day, when the machine is in constant action. They must not press heavily upon the axis, but the pressure should be increased until most of the sparking is taken up. These sparks, given off by slight breaks in the circuit, soon burn the brushes and contact pieces.

Gramme's machines are now made in several sizes, to give from 2,000 to 16,000 candle lights, with horse-power required of from $1\frac{1}{2}$ to 6, and in weight from 1 to 8 cwts. Cost, from £50 to £300.

Fig. 40 illustrates one of the large machines constructed by Gramme, for the production of large currents. It has 6 bar magnets, 2 rings, and weighs 1,540 lbs. The copper wire upon all the magnet bars weighs 400 lbs., and upon the ring 80 lbs. It is found to give an electric light of about 4,000 candles, but is not so well adapted for electric illumination on the arc principle as for the working of incandescent lamps.

Two of Gramme's 16,000-candle power machines were employed to burn the electric candles on the Thames Embankment. One of these machines burns 20 "candles." The connections in the ring of this larger machine are not made all on one side. There are 120 radiating slips, 60 on each side of the ring. These lead to two collecting cylinders, and four collecting pads press upon these cylinders to take up the currents.

Work of the Gramme.—In a communication to the Academy of Sciences, M. Tresca gives an account of a series of experiments which he had instituted for the purpose of determining the work performed by the dynamo-electric machines of

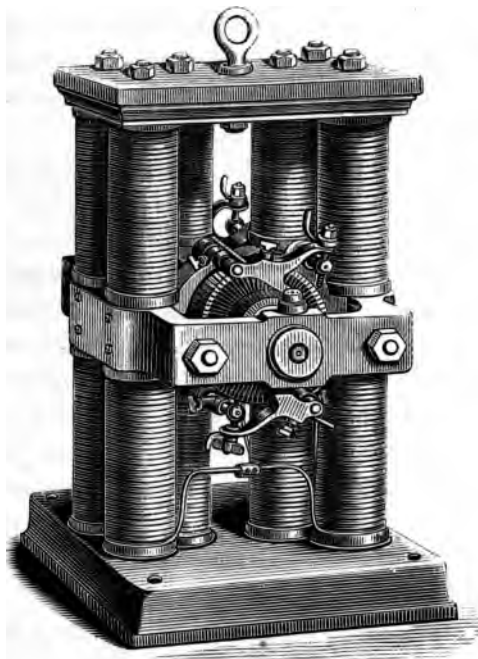


Fig. 40.—Large Gramme Machine.

M. Gramme. His experiments had reference to two machines emitting light equivalent to 1,850 and 300 Carcel lamps respectively.* These particulars will be found in *Van Nostrand's Magazine* for June, 1876.

* The Carcel lamp is a standard in France, consuming 648 grains of pure oil per hour. Its value in English standard candles is about 13, or, roughly, it is equal to a gas-jet consuming 4 cubic feet per hour.

A similar series of experiments were carried out at the French Northern Railway dépôt, with Gramme machines of 50, 100, and 150 Carcel lamp power respectively. The power necessary to drive the machines was ascertained by a comparison with engines driven by gas or steam, of 2, 3, or 4 horse-power, used either separately or coupled. Previous determinations, carefully ascertained, however, with a Prony dynamometer, had given the relative volume of gas consumed to the power derived (*i.e.* useful work), all the conditions remaining the same.

The lamps employed in the experiments were of the Serrin type, and answered the purpose remarkably well. The following results were obtained. The horse-power is given in Force de Cheval = 0.9876 of a horse-power.

Number of revolutions of bobbin per minute	Dynamo-Electric Machine of		
	50-Lamp Power.	100-Lamp Power.	150-Lamp Power.
	1,650	800	800

Power necessary to secure a steady light—

With carbons 0.007 m. apart . . .	2.2 ch.	2.4 ch.	2.5 ch.
Ditto 0.009 m. apart . . .	„	2.6 ch.	2.7 ch.

Consumption of carbons, including waste—

With carbons 0.007 m. apart—			
At positive pole	2.2 ch.	0.090 m.	} 0.135 m.
Ditto at negative pole	„	0.045 m.	
With carbons 0.009 m. apart—			
At positive pole	„	0.060 m.	} 0.090 m.
Ditto at negative pole	„	0.030 m.	

The following figures will be of interest as exhibiting the comparative cost of electric lights

and gas, as ascertained through the experiments undertaken by the Northern Railway Company of France.

Taking, for example, the lamp of 150 Carcel lamps, and allowing it to emit light for 10 consecutive hours in some spacious hall or railway dépôt: 150 Carcel lamps will require a consumption of 150×0.105 mc. of gas per hour, equal to 15.75 m., which, at the rate of 0.36 fr. per cubic mètre, would constitute an expense of 5.70 frs. In the use of electricity for the illumination, 150 Carcel lamps require 2.7 ch., which, at the rate of 0.09 fr. per horse-power per hour, including cleaning and lubrication, the expense would amount to 0.24 fr. Adding to this 0.09 fr. for carbons, 0.45 fr. for wages to the employé, and 0.20 fr. for the interest and liquidation of the expense of instalment, the total amount would be 0.98 fr., or, in other words, between one-fiftieth and one-sixtieth of the expense involved when using gas for the illumination.

An electric light of 150 Carcel lamps lights up advantageously a circle of about fifty mètres in diameter, and it is evident the illumination by electricity, being so much superior in intensity, ought to be more economical than gas, since the illumination of the *same area* requires the light of more than twenty-five gas jets, consuming 105 litres per hour.

The best make of Gramme machine now produced, of the 6,000-candle type, is, length, 1 ft. 11 in.; breadth, 1 ft. 3 in.; height, 1 ft. 8 in.; weight,

3 cwt. 1 qr. 22 lb.; horse-power absorbed, 2·5; revolutions per minute, 850; light in standard candles, condensed beam, 6,400; diffused beam, 4,000; *light produced per horse-power*, in standard candles, condensed beam, 2,560; diffused beam, 1,600.

The following are a few particulars given by the British Electric Light Company of Gramme dynamo-electric machines.

Class.	Light in Standard Candles.	Horse-power required.	Revolutions per Minute.	Weight.	Extreme Dimensions.			Price.
					Length.	Breadth.	Height.	
				cwts.	ft. in.	ft. in.	ft. in.	£
O	800	1½	1,600	1½	1 6	1 2	1 4	60
M	2,000	1½	1,600	1½	1 6	1 2	1 4	60
A	6,000	2½	900	3½	2 4	1 4	1 11	75
C	†15,000	5	700	8	2 5	1 10	2 2	—
	*25,000	8	1,200					
D	†25,000	8	300	20	3 2	2 8	2 8	—
	*45,000	13	500					

† Tension.

* Quantity.

The intensity of light here quoted is approximately that given by a machine working with a Serrin lamp in good order. When other lamps are used, the intensity of light may differ from the above results. The figures are given as a guide only.

Gramme's Distributor Machine.

For the Jablochhoff candle, consisting of two carbons placed parallel and insulated from one another, which will be described farther on, alternate currents are required, and for this purpose, and for producing currents in several separate circuits

M. Gramme devised a machine called the "distributor," which is used in conjunction with an ordinary Gramme machine.

The machine in external appearance resembles a wooden drum fixed by feet and bolts to a firm base.

Directly inside the drum surface is a flat ring of iron, divided into 8 sections, and half of each section is coiled alternately right and left with covered wire. The whole outside system is therefore simply 8 flat curved electro-magnets. Within this circle, projecting from the axis of the machine like the spokes of a wheel, are 8 wide and flat electro-magnets, which are also wound with wire alternately right and left, their exterior poles being thus alternately north and south. This central system is caused to rotate, and into the coils of the magnets is passed the current from an ordinary Gramme generator. There is no actual connection between the revolving system and the outer 8-section ring. The electro-magnets act as usual by induction upon it, and cause each section to give off alternate currents. These sections may be subdivided again into right and left subsections. The subsections may also be wound in one direction as in the Gramme ring. The wires of the central rotating electro-magnets form one continuous circuit, and the current is simply passed into it by a pair of copper wire brushes pressing upon two copper rings connected to the extremities of the circuit. The speed is from 300 to 600 revolutions per minute, with horse-power of from

10 to 16, and it is usual to drive both generators and distributors from one engine.

These machines are constructed to provide from one current several separate currents, each capable of maintaining one or more electric candles in action.

Taking two notable examples of the application of this machine, it was the one used to distribute the main currents to Jablochkoff's candles as employed lately in Paris. It is the machine in use in the illumination of the Thames Embankment. In this latter instance of electric illumination, the main generators (of which there are two) are 16,000-candle power Grammes; the current from these is passed into the distributing machines, which send alternate currents into 4 circuits, in each of which there are 5 candles.

Gramme's Combined Exciting and Dividing Machine.

This is a new form of the Gramme apparatus recently introduced. In it the exciting ring and "distributing" or "dividing" coils are combined and form one machine. Figs. 41, 42, 43, and 44 represent this apparatus.

The machine, a general view of which is given in Fig. 41, is arranged as follows: On a cast-iron foundation are fixed two plates of the same metal, almost circular in shape, forming the standards upon which the electrical parts are mounted. They are connected together by six square bolts, and

are provided with bearings for the main shaft (see longitudinal section shown in Fig. 42). One of these plates is furnished on the inner side with a circular rib, on which are mounted the electro-magnets for exciting the ring, as shown by the cross section Fig. 43. As in the model previously described, the coil for the alternating currents rests on the square bolts connecting the end plates of the frame with packing pieces of hard wood. One end

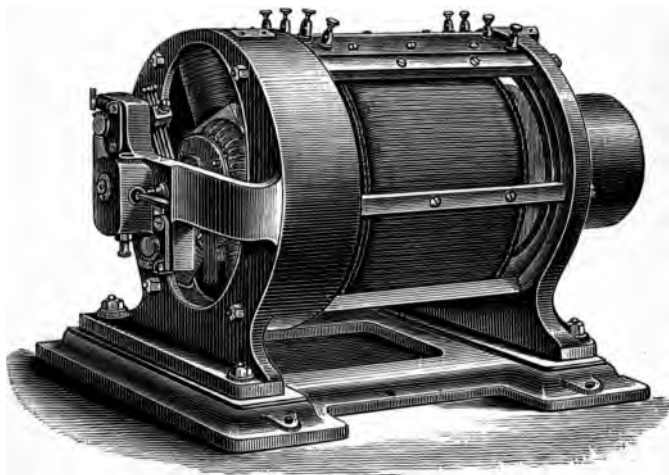


Fig. 41.—Gramme's Combined Machine.

of the frame thus carries the electro-magnets of the exciter, while the central portion supports in position the large flat coils of the distributor, shown in cross section in Fig. 44. Upon the main shaft is mounted, at one end, the exciting coil, which revolves between the poles of the fixed electro-magnet, see Fig. 43. The central portion of the

main shaft carries a hexagonal sleeve, upon which are bolted the six electro-magnets of the large distributing coil, shown in cross section in Fig. 44. The shaft thus carries at one end the exciting coil, and upon its central portion the six electro-magnets, radially arranged, which induce the currents in the distributing coils, see Fig. 42. Wide bearings are employed, and in the larger machines a system of automatic lubrication is in use.

An arm carrying a wire brush, shown in the

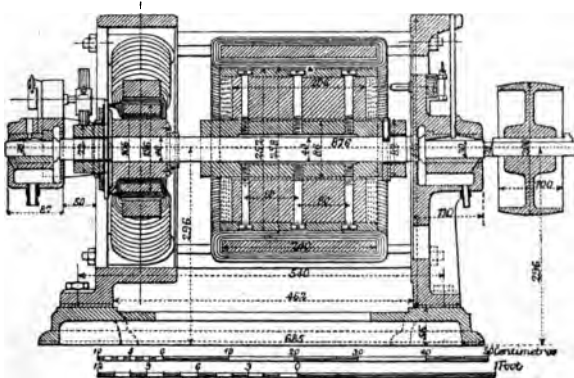


Fig. 42.—Gramme's Combined Machine.

longitudinal section, Fig. 42, serves to place in communication the coils of the moving electro-magnets with the exciting ring. The current is collected and transmitted by small brushes of silvered copper wire. The brushes are worked by means of a small endless screw. For regulating the power of the machine, a copper wire, the length of which can be varied at will, is introduced between the exciter and the electro-magnets. The method of coiling

the wire differs slightly from that adopted in the other machines, as, instead of winding only one wire, two are coiled, in order to obtain by this mode of coupling tension currents for small lights, or quantity currents for large ones. Two types of this machine are now manufactured. The smaller weighs 616 lbs., and supplies 12 candles of from 20 to 30 Carcel burners, or 8 candles of from 40

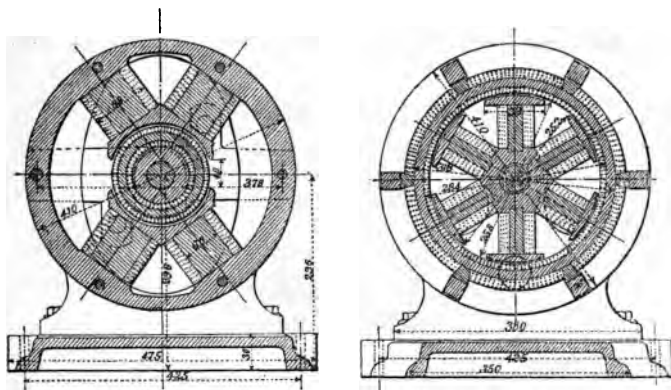


Fig. 43 and 44.—Gramme's Combined Machine.

to 50 burners. The larger machine weighs 990 lbs., and furnishes power of 24 candles of 20 to 30 burners, or 16 of 40 to 50. The following table contains the results of some recent experiments with these machines :—

Number of revolutions per minute.	Horse-power expended.	Number of lamps.	Power of each light in Carcel burners.
1400	5	12	28·5
1425	6	8	43·0
1200	4	6	48·5
1000	13	16	48·0
1020	13	16	51·3
1200	14	24	31·0

With a machine specially arranged for small lights, there have been obtained, with a speed of 1,250 revolutions, 14 lights of 20 Carcel burners each, with an expenditure of 4.66 horse-power. The candles employed had carbons 3 mm. ($\cdot 12$ in.) in diameter. In all the experiments made a much steadier light was obtained than that given by the machines employing an independent exciter.

An application of this machine was made on board the *Cosmos*, a ship built by Messrs. Inglis & Co., of Glasgow and Greenock, for the *Messageries Fluviales à Vapor*, in South America, for running on the rivers Plata and Uruguay. The machine employed is capable of producing 8 large or 12 small lights, and, running at a speed of 1,500 revolutions per minute, maintains 8 lights of 50 Carcel power, each with an expenditure of 6 horse-power. The lights are distributed as follows:—Three in the upper saloon, three in the lower saloon, one on the landing of the stairway leading from the upper to the lower saloon, and one over the gangway. The machine, which is fixed on deck amidships and under the paddle-wheel shaft, is driven by a vertical engine with a cylinder $4\frac{1}{4}$ in. in diameter, and $4\frac{1}{2}$ in. stroke. The experience obtained at the trial of this light was in every way satisfactory.

Siemens' Machines.

Continuous Current Machines.—The usual form of the Siemens' machines for the production of con-

tinuous currents is represented in Figs. 45, 47, and 48. The distinctive feature of the machine lies in the armature, which is a development of

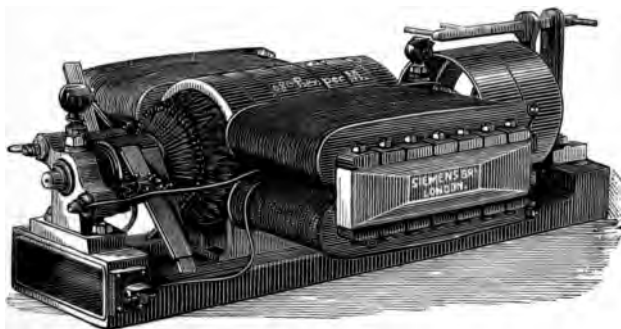


Fig. 45.—Siemens' Continuous Current Dynamo Machine.

the original armature introduced by Dr. Siemens, and represented in connection with the Wilde machine.

Siemens' improved armature consists of a hollow soft iron cylinder, mounted upon an axis in the direction of its length.

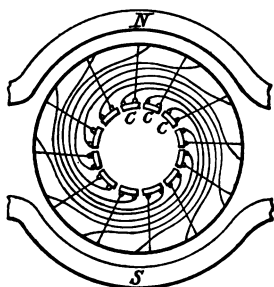


Fig. 46.—Diagram of connections in Siemens' modified armature.

Every portion of the exterior surface of this cylinder, including its ends, is covered by a wire envelope several layers deep. The wire is arranged in sections, and connected together so as to throw the active sections into the circuit at the right moment, or at the instant when they become

the original armature introduced by Dr. Siemens, and represented in connection with the Wilde machine.

active, by cutting the magnetic field. The wire is wound on the armature in a peculiar manner of grouping invented by Häfner von Alteneck. Each convolution is parallel to the axis of the cylinder, and the wire is arranged in 6 sections of two coils each, having 24

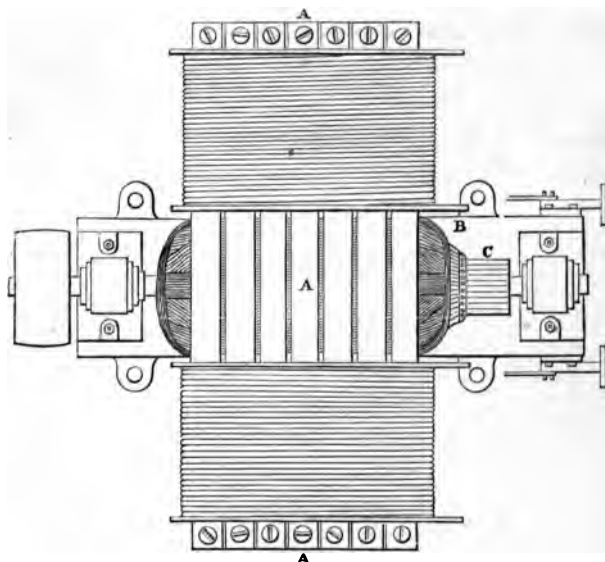


Fig. 47.—Siemens' Machine: Plan.

extremities, which are connected up so that two of those ends are connected to each of the segments of a circular commutator having 12 divisions. The arrangement of the sections of the wire envelope may be better understood by reference to Fig. 46, which represents the commutator end of the armature. N and S represent the poles

of the field-magnet, situated in this machine upon a vertical line passing through the axis of the armature. The central portion of the diagram is intended to show the arrangement of the extremities of the wire coils. C C, etc., are a series of 12 copper plates arranged upon and parallel to the axis of an insulating cylinder called the commutator. Each plate is furnished with two connecting screws to receive the wires. The sections are so connected to the plates that, while the commencing end of No. 1 section is attached to No. 1 commu-

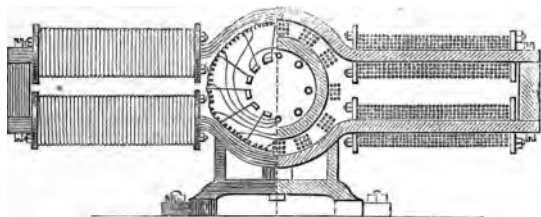


Fig. 48.—Siemens' Machine: Section.

tator plate, the finishing end of the same section is carried round to the plate diametrically opposite, as represented. The same arrangement is carried out with the other sections. It is difficult, however, to represent the arrangement of the wires in this armature by diagrams or written description.

The machine itself, the horizontal form of which is represented in Fig. 45, will be seen to consist of a cast-iron base-work, upon which is bolted a large

electro-magnet of peculiar construction. The base also carries bearings to receive the axis of the armature and the driving gear. The field-magnet is composed of 14 soft-iron bars, 7 of them being placed above, and 7 below the armature. These iron bars are curved to embrace a great portion of the armature above and beneath, and are connected together by iron junction blocks at their ends, as represented in the figure. This arrangement forms the iron core of a large flat electro-magnet, with two central poles as before explained. It is excited by a current passed through 4 flat bobbins of insulated wire, arranged in the manner shewn in the engraving.

Fig. 47, shewing a plan of the horizontal form of machine, will render this arrangement more intelligible. A and A represent the upper portion of the field-magnet, B the armature cylinder, and C the commutator from which the currents are collected.

Fig. 48 is a cross-section of the same machine. In this view, only the half to the right of the diagram is in section, exhibiting the armature and the electro-magnet.

Reverting to Fig. 45, it will be observed that the collecting "combs," as the commutator springs are termed, are arranged in pairs at diametrically opposite sides of the commutator.

This completes the more essential constructional features of the machine. The field-magnet is excited in two different ways, according to the kind

of work the machine is intended to perform. In the first place, the wire coils are so connected together as to act as one continuous length of wire, and this is so disposed as to cause the magnetic polarity of the arrangement to concentrate itself above and beneath the armature. If the machine is intended to work in a circuit not subject to sudden variations of resistance, the magnet coils are made of thick wire, and the whole of the current evolved by the magnet is passed through them, and thence to the exterior portion of the circuit. In this arrangement, the whole of the wire active in the machine is in the main circuit at once.

It will be observed, however, that if an electric lamp were included in the circuit, and if it be of a kind liable to produce great variations in the resistance, an increase of resistance would weaken the current, which, reacting upon the field-magnet, would diminish its power. In this way, great variations in the intensity of the light would be produced, because the current becomes weaker just when it should become stronger, and *vice versa*.

For these reasons, the electro-magnet of the Siemens' machine is frequently made to act as a "shunt," or derived circuit from the main circuit. In this arrangement, the magnet is wound with much finer wire, and the current from the armature, after being collected by the "combs," is divided into two parts, the one being passed through the electro-

magnet coils, and the other flowing in the main circuit. The effect of this arrangement is that, when the exterior resistance increases, a large proportion of the total current is caused to pass through the electro-magnet, thus increasing the intensity of the magnetic field and the power of the machine to overcome the exterior resistance; and conversely, when the exterior resistance diminishes, less of the current passes through the electro-magnet, and its power is diminished in proportion. A continuous balancing of the power of the magnetic field and the work done in the exterior resistance thus goes on, the power of the machine becoming greater and less as it is required. These machines are called "shunt wound" machines.

In some forms of the machine, or when several machines are used together to maintain a series of electric lamps, it is found most advantageous to excite the electro-magnets by an independent machine of small size. In the action of one form of the Siemens' machine alternating currents are produced. It is therefore impossible to excite the magnets of the machine itself by means of those alternating currents. In such cases a small continuous current machine, called an exciter, driven from the same engine, is employed. The exciter is generally of the type represented in Fig. 49. It is essentially the same kind of machine as that already described, but of smaller size, and arranged vertically, so as to occupy as small a floor-space as possible.

In one form of the large Siemens' machine the iron cylinder of the armature is a fixture, and the wire envelope revolves over it. In this case the machine is provided with double sets of bearings, the outer set being merely supports for the central fixed shaft to which the stationary iron cylinder is attached, and the inner pair in which the axis of the

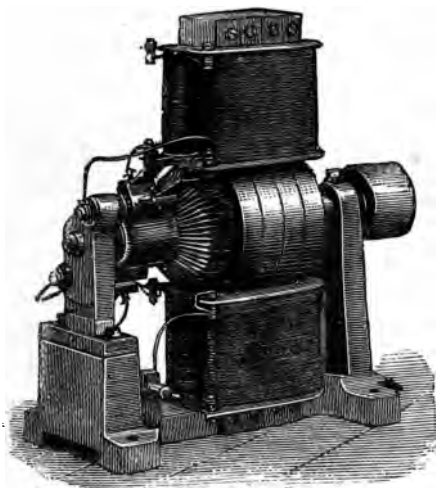


Fig. 49.—Siemens' Continuous Current Exciting Machine.

wire envelope rotates. The wire is coiled upon a cylinder of German silver, to which the axis and driving-pulley, with the commutator, is attached. The other portions of the machine are the same as those already spoken of. Fig. 50 represents the fixed cylinder machine in section, the bearings for the fixed shaft being omitted.

When the Siemens' machine is set in motion there is little resistance, but a few turns of the armature are sufficient to collect in its coils, from the feeble induction of the residual magnetism, enough electricity to greatly strengthen the magnetic poles, which induce stronger currents in the coils, and this continues, on the principle of mutual accumulation, until the magnet is saturated and the machine gives its strongest current.

The magnetic poles act strongest upon the coils

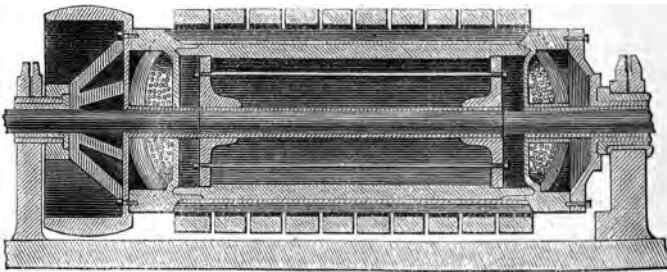


Fig. 50.—Siemens' Machine with fixed armature : Section.

just as they pass the vertical line passing through the axis, and the weakest currents are produced as the coils pass the horizontal line. These are called the maximum and minimum points. Currents are thus induced as the convolutions of wire approach either of the magnetic poles. The currents are at once taken off by the collecting brushes, and pass in a constant direction through all the coils of the electro-magnet, from the two ends of which the current is taken for the external circuit in the usual

way. All the wires employed are, of course, insulated, by being covered with gutta-percha, tarred hemp, or cotton and silk.

The following table contains some particulars of Siemens' continuous current machines.

Type of Machine.	Number of Lights.	Light Power in Standard Candles of each light.	Diameter of Pulley in Inches.	Width of Machine Strap in Inches.	Number of Revolutions per Minute.	Horse-power required, about—	Price.		
D ₉₀	1	50,000	15	9	400	20	£	s.	d.
D ₀	1	30,000	12	8½	500	15	360	0	0
D ¹	1	12,000	10	4	550	7	290	0	0
D ²	1	6,000	8½	3½	600	4	220	0	0
D ⁷	1	3,000	6½	3	950	3	95	0	0
D ³	1	2,000	7	3	950	2½	70	0	0
D ⁶	1	1,300	6	2½	1,300	2	65	0	0
D ⁵	1	500	5	2½	1,200	1½	55	0	0
SD ₇	3	1,000	6½	3	950	3	45	0	0
SD ₈	6	1,000	8½	3½	950	5½	75	0	0
							110	0	0

The above speeds are for a circuit of low resistance; for higher resistances the speed must be increased. With each machine two spare sets of commutator combs are supplied.

Several lighthouses are now illuminated solely
• by the above machines. The smallest size would

appear to be in most favour, as they may be readily coupled together, which is often required in thick weather to produce a powerful light, which would be unnecessary in clear weather. They have been adopted by the Trinity Board at the Lizard lighthouse, where six of the small machines are fixed. Of the competitive trial brought about by the Trinity Board, to determine the most economical machine for lighthouses, superintended by Professor Tyndall and Mr. Douglas, engineer to the Board, it will be unnecessary here to speak at length. The Siemens is known to have given the best results. Of the working of Siemens' machines the author has had practical experience, and can testify to their excellent performance. The machines keep cool, which is a great advantage in continuous working.

The Siemens' Alternating Current Machine.

Dr. Siemens in 1878 patented an alternating current machine, Fig. 51. It consists of a central disc carrying bobbins. This disc is on a shaft and revolves between two sets of electro-magnets ranged in circles on each side of the disc, having their axis parallel to the shaft. The bobbins have no iron cores, and the heating caused by the magnetising and de-magnetising of the iron is thus avoided. The electro-magnets are excited by a small Siemens' continuous current dynamo machine.

These alternating current machines, which are made in a variety of sizes to maintain from 4 to 60 of Siemens' differential arc lamps, are also adapted for use with Jablochkoff's candles, or with Swan's incandescent lamps. Their field-magnets are all

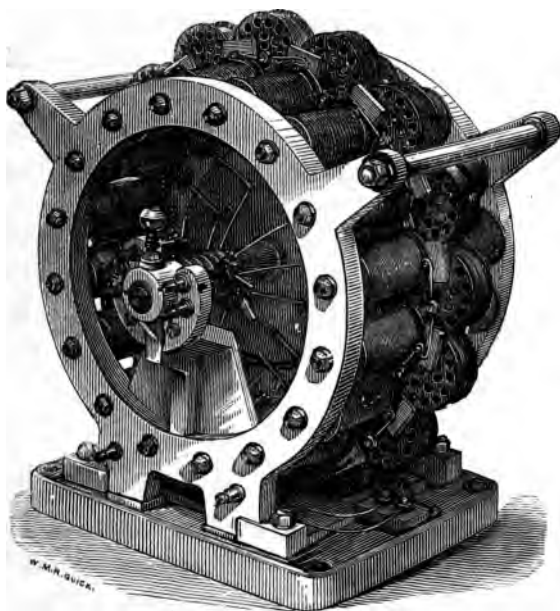


Fig. 51.—Siemens' Alternating Current Machine.

excited by continuous current machines of varying sizes; the main machines absorb from 4 to 40 H.P., and the excitors from $1\frac{1}{2}$ to 4 H.P. The price of these machines, with the exciter, is from £170 to £535.

The Farranti-Thomson Machine.

This machine is the joint invention of Messrs. Farranti and Thompson in co-operation with Sir William Thomson. It has been the subject of much discussion, and although it may be considered as extremely simple in design and construction, its performance is regarded as excellent.

It consists essentially of a two-sided frame and two sets of electro-magnets as in Siemens' alternating current machine, a view of which is given Fig. 51, on p. 130. There is no difference between the two machines so far as the arrangement for the production of an intense magnetic field is concerned. In the Farranti machine (as we may now term it) the two vertical plates, as in Siemens' machine, carry each 16 soft iron cores with their axis parallel to the shaft. Each core is wound with four layers of insulated wire one-seventh of an inch in diameter. The helices are connected in series. The soft iron cores are, when the current flows around them, magnetised alternately north and south (as it is usually termed). The N. poles upon one side are opposite to the S. poles on the other side; between the two circles of poles a series of intense magnetic fields is thus produced. The electric resistance of the series of helices is 2.5 ohm. The magnetic field is produced by the passage of the current from Siemens' small ex-

citing machine, the current evolved being about 21 ampères.

The armature of the machine presents the chief

features of interest. Its precise construction has not been made public up to the time of writing this notice, owing to the delay involved in securing the patent-rights in foreign countries; but it is generally known to electricians that it consists essentially of a copper tape, arranged

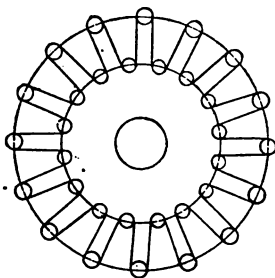


Fig. 52.—Arrangement of Farranti's Armature.

in several layers upon winding-pins, somewhat after the manner represented in the diagram, Fig. 52. In the machine lately exhibited in London by Messrs. Hammond, it is understood that the copper tape is wound upon the frame of the armature in the form of a flower of eight petals (so to speak). The diagram shows 16 of such loops, as shown in the inventors' specification. The number employed will obviously depend upon the number of magnets and the velocity of rotation in different sizes of the machine. The copper tape is said to be 120 feet in length, $\frac{1}{8}$ -inch in width, and $\frac{1}{12}$ th inch in thickness, wound in 12 layers. It weighs about 18 lbs., and offers a resistance of 0.265 ohm. The currents produced are alternating in direction.

This form of construction, which will probably be considerably modified in the future, presents

two advantages. Electrically it allows of the armature being made in the form of a thin star, so permitting the development of a very intense magnetic field between the opposite poles of the magnets. This field is cut by such an armature in its most intense region, and the result is a high efficiency of the machine. It also admits of the machine being made of less weight and bulk than ordinary machines. The weight of copper employed is much less than that usually found necessary. From these considerations it is obvious that the Farranti machine can be sold at a much less price than most other machines. It is claimed for the machine that its efficiency is from 80 to 90 per cent. ; that it can maintain 12 or 13 of Swan's 18-candle incandescent lamps per H.P. absorbed, and that, while it costs only £250, it is equal to many other machines costing £500.

In the course of the trials in London, the machine, exciter, and shafting absorbed in all 35 H.P., of which it was considered that the machine itself absorbed about 25 H.P. The total number of 18-candle incandescent lamps maintained was 320. The machine had an electromotive force of 125 volts, and the lamps, which each required an E.M.F. of 41 volts, were worked in parallel circuit, in series of three. Each lamp had a resistance of about 32 ohms when hot, and required a current of about 1.28 ampère.

Maxim's Machine.

Fig. 53 represents a dynamo-electric machine, patented by Mr. Hiram S. Maxim, of New York.

It will not be difficult to trace in the arrangement of the parts a distinct resemblance to the Siemens' machine.

The curved electro-magnet bars are bolted to a stout cast-iron projection from the base, and form, in fact, the framework of the machine. They extend upwards, are curved at the middle to provide a cylindrical chamber for the armature, and

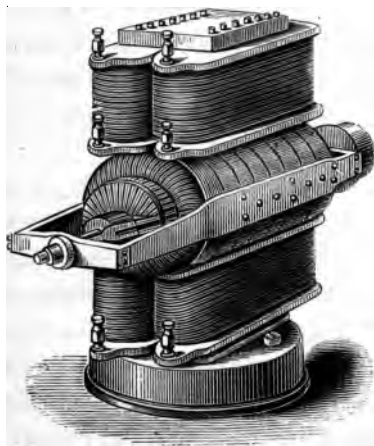


Fig. 53.—Maxim's Machine.

are finally bolted to a metallic plate forming the crown of the machine. Just above the base are placed a pair of flat wire bobbins, closely embracing the electro-magnet bars, and above the curved central portion are fixed another similar pair of bobbins. This forms the electro-

magnetic system of the apparatus, which is very simple so far.

Along the sides of the bars, just opposite to the *central line* horizontally, are bolted two stout side

frames. These carry between their ends the supports or bearings of the axis of rotation.

The armature of Maxim's machine consists of a hollow iron cylinder enveloped by numerous convolutions of insulated wire. The arrangement is similar to that of the Gramme armature, the only difference being that the iron portion consists of a cylinder instead of a ring. The enveloping coil consists of 16 helices of copper wire, each helix consisting of 4 wires, the extremities of which are connected to the 64 sections of the commutator cylinder in the manner already described in reference to the Gramme machine. The collecting brushes are attached to an adjustable frame, capable of movement upon the axis, and an arrangement is provided by means of which the brushes may be caused to bear at greater or less distances from the points of maximum currents. This arrangement is made to serve as a regulator of the current by an ingenious adaptation of electro-magnets and adjusting levers (not represented in the engraving), controlled by the current in the main circuit. Maxim's machine is chiefly used in connection with the same inventor's incandescent lamps.

Wilde's Dynamo-Electric Machine.

Mr. Wilde, in 1866, took out a patent which forms the basis of a dynamo-electric machine, which he eventually completed in its design in 1873. It consists, for the framework, of two cast-iron cir-

cular plates, placed vertically and kept the requisite distance apart by stay rods. Each plate carries, projecting from its inner face, a series of electro-magnets, sixteen in number. These fill up the greater part of the space between the frames. Through the centres of the frames is passed the shaft, which carries a large cast-iron disc, rotating between the two sets of electro-magnets. This

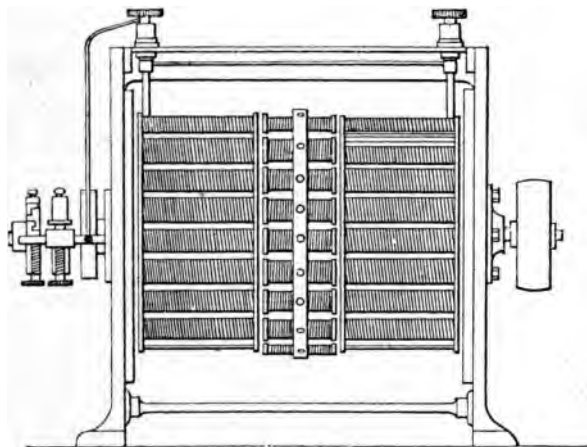


Fig. 54.—Wilde's Dynamo-Electric Machine : Front Elevation.

cast-iron rotating disc carries sixteen soft-iron cores, passed through the disc. The projecting ends of each core are wound with wire; thus they form 32 armature electro-magnets. These are connected so as to form eight groups of four each, and the current from one of these groups is used to excite the circles of field electro-magnets, whilst the remaining seven groups are employed to give the current

for external use. By an arrangement of commutators the currents produced can be obtained direct or alternating. This machine is extensively used by the Admiralty in the large ironclads, where it is driven by a Brotherhood engine connected direct to the shaft.

Figs. 54 and 55 will give some general idea of the arrangement of the parts in this machine.

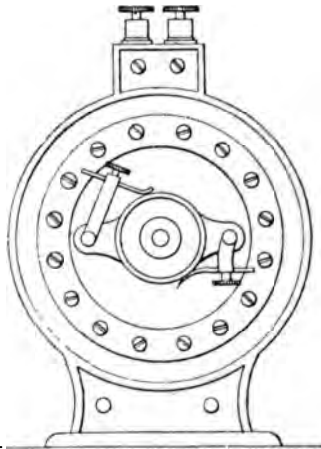


Fig. 55.—Wilde's Dynamo-Electric Machine : End Elevation.

Weston's First Machine.

Fig. 56 exhibits the external appearance of this apparatus.

Fig. 57 shows the central arrangement of magnets. There are two sets, the inner, on the shaft, and the outer, fixed to the cast-iron drum. Each set is composed of six magnets. They are

arranged in pairs, forming three pairs of horse-shoe magnets. The length is less in the inside set than in the outside set, which is made fast to the iron drum by screws as represented. These magnets are composed of malleable cast iron, and are of a shape which gives them great inductive strength

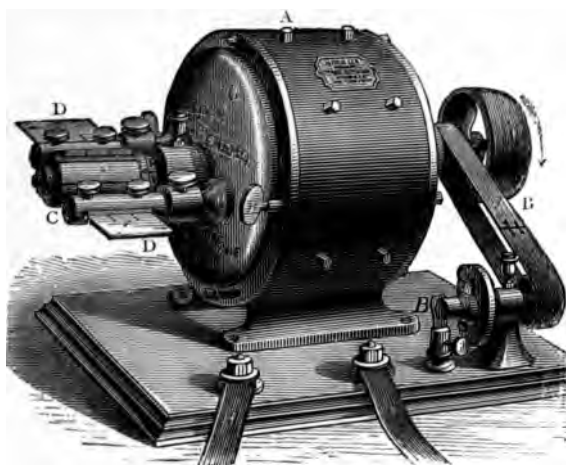


Fig. 56.—Weston's First Machine.

in little space. It will be observed that, with reference to the outside set of magnets, the cylinder or drum itself forms the magnetic connecting link between them. The drum being of cast iron, of considerable hardness, permanently retains, as indeed do the magnets themselves, sufficient residuary magnetism to start the machine in action as soon as the central system is put in motion.

After coiling, the wires are taken off in three

pairs. Those wires from the N. poles, for example, are carried to one portion of the commutator, Fig. 58, and those from the S. poles to the other portion. The wire is finer for the inner than for the outer set of magnets.

After the currents are generated in the central set constituting the armature, they pass to the contact brushes, and from these they are at once led into the circuit of

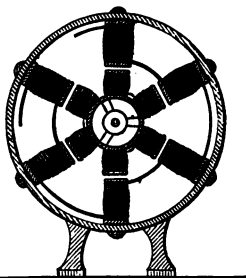


Fig. 57.—Weston's Machine:
Section.

the outside set of magnets by the ends of the wire shown disconnected in Fig. 57. This can be done because the outside system circuit is complete, the wire being wound, without break, over each bobbin in succession. One contact brush is connected to one end of the outer magnet circuit, and the other is connected to one extremity of the external resistance, the second end of which is connected to the remaining extremity of the magnet portion of the circuit. The contact brushes are shown at D D, Fig. 56.



Fig. 58.
Weston's
Commutator.

Much care is taken so to adjust and turn up the faces of the two sets of magnets that they may pass each other as near as possible without actually touching.

The polarity of the armature system is continu-

ally being changed when the machine is in motion, because the outside magnets always have like polarity, and by induction change the poles of the inner system six times in one revolution. The inner system should always, in these machines, be of the softest and finest iron, because the changes of magnetic polarity are exceedingly rapid, and much heating, with loss of current and power, must result in the employment of cast or hard iron.

Six impulses are given off at each revolution, and as these are in alternate directions, they are converted into three direct impulses by the commutator. Because these currents are not constant in strength throughout each revolution, the speed should be high in employing the machine for electric light.

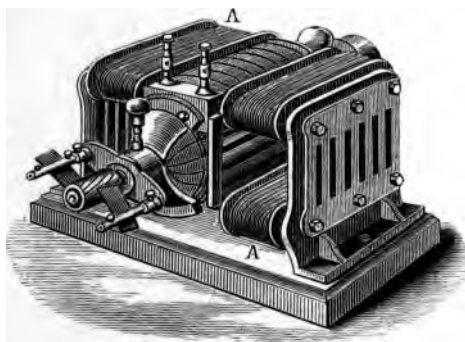


Fig. 59.—Weston's New Machine.

Weston's New Machine.—The general arrangement of this machine is exhibited in Fig. 59, where A A represent the magnet coils. It will be

observed that this part of the apparatus is similar to that of Siemens. The pole pieces, or plates, crossing the armature and embracing it for part of its circumference, are composed of iron plates, placed side by side in a mould, but separated a uniform distance from each other. As the plates are thus set in the mould, the iron magnets on which the wire is to be wound are cast on to "lugs," or projections, on the ends of the plates. The two cast-iron ends and uniting plates form one magnet; the upper and lower magnets are alike, and when joined together by the perforated vertical supports, the inner curved edges of the field-plates embrace about two-thirds of the circle in which the armature is to revolve.

It will be thus seen that the inventor prefers to employ cast iron and malleable plate in his magnets, making the crossing curved prolongations only from boiler or other rolled plate.

Fig. 60 represents the unwound armature, or revolving portion of the machine. It is built up of

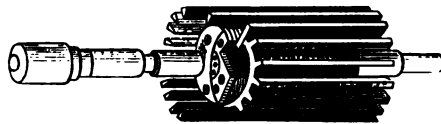


Fig. 60.—Weston's Armature.

plates which are somewhat like a cogged wheel in shape. These plates are stamped out of sheet iron, and when mounted on the shaft are separated from each other at a uniform distance. The radial

projections are then arranged in lines, so that the whole forms a very broad cogged wheel, or cylindrical structure, having longitudinal grooves with transverse spaces at regular distances. The longitudinal grooves are intended to carry the wire, and it will be observed from the nature of the structure that the wire lies in channels three sides of which are iron, so that the mutual effect upon each other is increased as much as possible.

The ends of the wire are connected to the commutator in the usual way, the currents travelling in one direction only to the field magnets. The commutator is fitted on a portion of the shaft which projects beyond the bearings: this admits of its easy removal, and a new one being fitted in a few minutes.

Another important feature in the construction is the arrangement for ventilation; the separation between the pole plates of the field magnets, the perforation in the vertical supports of the magnets, and the light framework of the armature are all for this purpose. The air enters the centre of the armature, and is driven out between the layers of wire through the spaces formed by the separated poles of the armature and field magnets, and thus prevents any part from becoming unduly heated. Machines of this description are made of various sizes and strengths, to give from one to sixteen lights in a single circuit.

This armature should furnish a very good return for the power expended in driving it, but the

stamping of its structural parts from sheet iron appears to be a mistake. Sheet iron is always hard, as rolled by the common process, and unless it is very carefully annealed to secure a softer structure, the magnetic poles of such an armature would not change polarity readily from N. to S., or the converse, in revolution. No doubt, however, the thinness of the various parts composing this ingenious armature will greatly aid its performance in practice.

Trouvé's Machine.

This machine is the result of an idea that a great gain in power would be obtained by doing

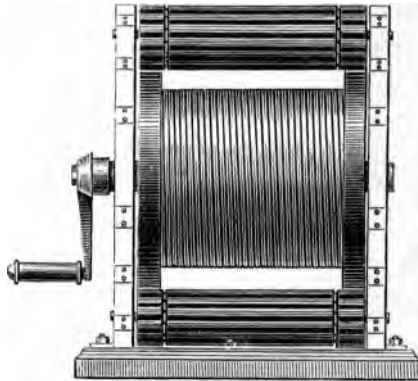


Fig. 61.—Trouvé's Machine.

away entirely with the space necessary in other machines between the moving and the fixed parts. M. Trouvé makes the large inducing magnet actually touch the cores of the induction coils, and

by these means causes the induction coils to revolve also.

Figs. 61 and 62 represent a machine on this principle, where the large central drum is composed of an iron core and ends, wound with wire as usual. This drum-like electro-magnet is surrounded with a frame of spokes at each end, and these frames carry two or more bundles of long, thin induction coils, which revolve in bearings as shown. This motion is caused by friction between the electro-magnet and the small cores. All the cores approaching the large magnet on one side of their circle have, say, negative currents induced, and those receding from it positive. A commutating arrangement is fixed to the axis of each bundle, and from this the currents are taken off, to be used separately (from each bundle) or in combination

with those from other bundles of cores actuated by the same electro-magnet.

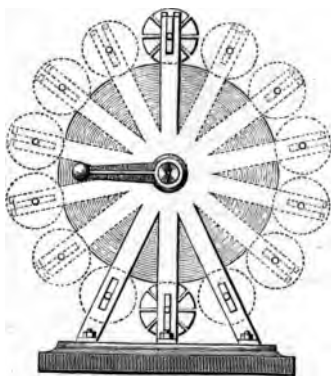


Fig. 62.—Trouvé's Machine: End.

This machine is, without doubt, theoretically good, but would appear to be a step in the wrong direction when regarded from a practical point of view. The friction of the parts is a very great objection

and will consume a great deal of power,

with great disengagement of heat and much wear. The noise must also be very great, and the whole apparatus exceedingly complicated, and in large size necessarily costly. If the inventor had struck upon the idea of obtaining actual contact by means of endless steel bands, he would probably have been nearer the practical solution of this problem. The same principle is applied to a machine similar to the Gramme, and it is said that this type of machine gives a light equal to 600 Carcel burners.

Lontin's Machine.

The machines identified with the name of M. Lontin are intended to produce currents in *a number of circuits from one source*. They consist

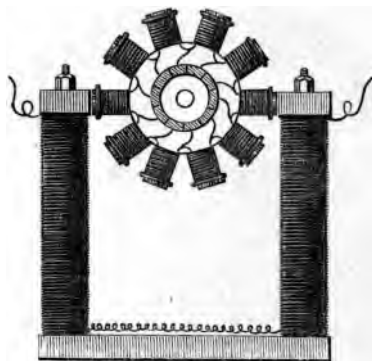


Fig. 63.—Lontin's Exciting Machine.

of a generating or exciting and a distributing machine.

Fig. 63 will give some idea of one of Lontin's first exciting machines, in which several bobbins

are arranged on a cylinder and revolve between the poles of the fixed electro-magnets. A commutator is arranged so as to give continuous currents.

The dividing or distributing machine is composed of a series of electro-magnets, M M, Fig. 64, radiating from a shaft or drum. These electro-

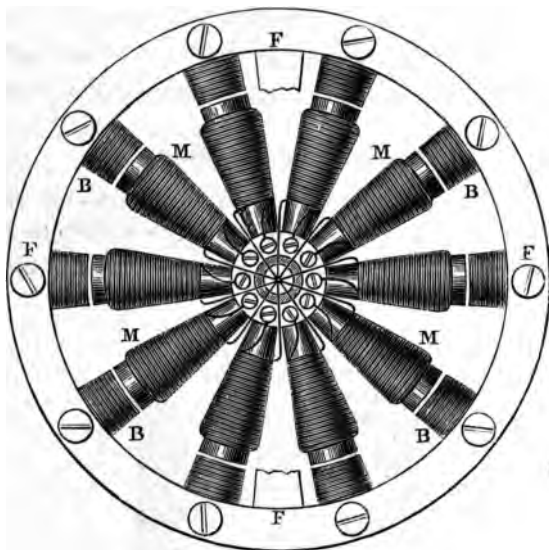


Fig. 64.—Lontin's Distributing Machine.

magnets are excited by the continuous current from the machine above described, and cause in their rotation induced currents to flow in the coils wound over the soft-iron blocks or cores B B, the circuits being taken from the bobbins B B direct; and those bobbins may be joined in pairs or otherwise, as *may best suit* the outside resistance to be worked

through. The machine is provided with a keyboard, upon which are fixed the binding screws and switches, to cause the currents to be subdivided to a number of lights. This machine, it will be seen, gives alternating currents.

If there are as many as 10 induction bobbins fixed to the outside frame F F, there will be a possibility of producing 10 lights in as many circuits; or, all those bobbins may be combined to produce one large light, or any number up to 10, as may be required. In this respect the Lontin machine is of much value. It is, in fact, a distributing machine.

In the latest machines of this maker the exciting machines have a number of bobbins upon a drum arranged in diagonal lines, as shown in Figs. 65 and 66, revolving between the fixed electro-magnets. By this ar-

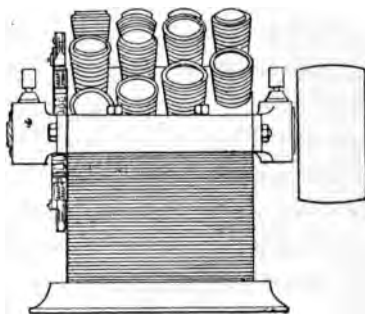


Fig. 65.—Lontin's Exciting Machine.

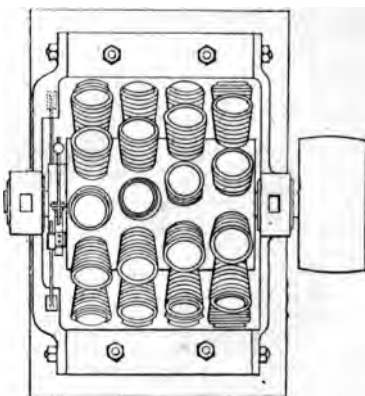


Fig. 66.—Lontin's Exciting Machine: Plan.

rangement the current is maintained more uniform in its strength.

Brush's Machine.

Although the Brush armature presents points of construction similar to those of Gramme's armature, the real difference between the two is greater than at first appears. Brush's ring differs from Gramme's in the arrangement and disposition of the wire helices enveloping it as well as in the method adopted in connecting the coils together. In Gramme's armature, as we have observed, the coils are arranged contiguously to one another, so as to completely envelope the ring, and the different sections are connected together so as to form an endless helix wound upon every part of the ring. In the Brush armature the individual coils are



Fig. 67.—Section of Brush's Armature.

separated from one another by a section of the iron ring as wide as each of the coils themselves. The sectional area of the ring between the coils is also much wider than in that portion enveloped by the

coil. This will be rendered clear by the view given of a portion of the ring in Fig. 67. The sunk por-

tions are intended to receive the coils, which fill them up to the level of the projecting sections. In the revolution of the armature between the poles of the field-magnets, the coils alternate with the masses of iron, which, from their enlarged section, are brought into as close proximity to the field-magnets as the coils are themselves. It will have been observed that this is also the distinguishing characteristic of the armature of M. De Meritens, already described. Gramme's ring is of soft iron; that of Brush of cast-iron, and generally of rectangular section.

Reverting to Fig. 67, it will be observed that not only is the periphery of the ring deeply grooved, but that the projections from its sides are separated into several portions by channels. The main object of this is twofold: it is first intended to allow

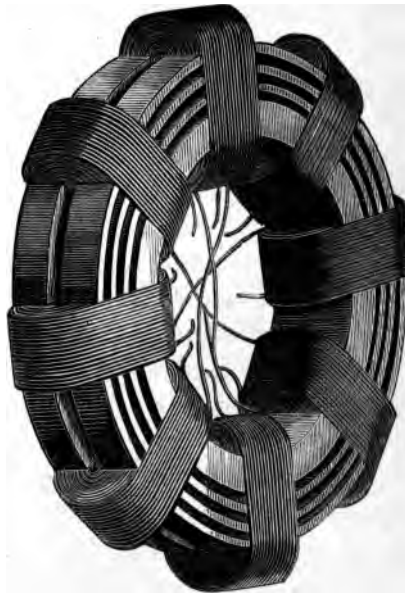


Fig. 68.—Brush's Armature.

of the circulation of air, and so maintain an even temperature in the ring, which, by rapid magnetic

reversals is very apt to become heated; and secondly, to prevent the development of induction, electric, or magnetic currents in portions of the ring itself, and thus allowing of the concentration of the inductive effect in the coils themselves. In the Brush 16-light machine the armature is 20 inches in diameter, and is wound with 8 radial coils of cotton-covered copper wire of the size known as No. 14 by the B. W. G. These coils are distributed round the ring at equal angular distances apart of 45 deg. Each coil consists of about 900 feet of wire, weighing about 20 pounds. All the coils are wound in the same direction upon the ring. The two sides of each of the coil-chambers, and therefore of each of the coils, are parallel to the radial plane of the coil, by which means the difficulty of coiling wire in a tapering chamber is avoided. Fig. 68, which is not drawn in strict proportion, exhibits the ring with the 8 coils in their respective positions.

The usual method followed in connecting up the coils is as follows:—The inner extremity of each of the coils is connected to the inner end of the diametrically opposite coil upon the ring. Thus, if we call the first coil No. 1, its inner extremity would be connected to that of coil No. 5. In the same manner the inner end of No. 2 would be joined to No. 6, and so on round the ring. All the outer extremities of the coils remaining unconnected are insulated from each other and carried to the commutator which rotates with the shaft. The two free extremities of diametrically opposite helices are

connected respectively to two diametrically opposite sections of the commutator. This portion of the machine, forming the surface from which the currents are collected in an uniform direction, is of peculiar construction. It consists essentially of two similar parts, insulated from each other and from the axis of rotation; each part consists of two flat cylinders of copper. The total number of portions is 4, and corresponds with the number of pairs of coils upon the armature. Each of these portions consists of two segments, insulated from each other, and separated by a segment of copper, as represented in the diagram (Fig. 69), where A and B are the contact segments, and C the separating segment referred to. This neutral segment, as we may regard it, is inserted for the purpose of throwing each pair of diametrically opposite helices out of the circuit during that period of their revolution

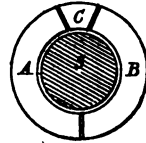


Fig. 69.—Portion of Brush's Commutator.

when they are inactive, or for 25 per cent. of the revolution. By these means the inactive pairs of coils are kept out of the circuit, which not only permits of the development of larger currents in the remaining coils, and reduces the resistance of the machine, but is believed to aid in a great measure in preventing the development of heat in the helices.

As will be observed in the general perspective view of the machine, given in Fig. 70, which is from a photograph of the 16-light machine, the dis-

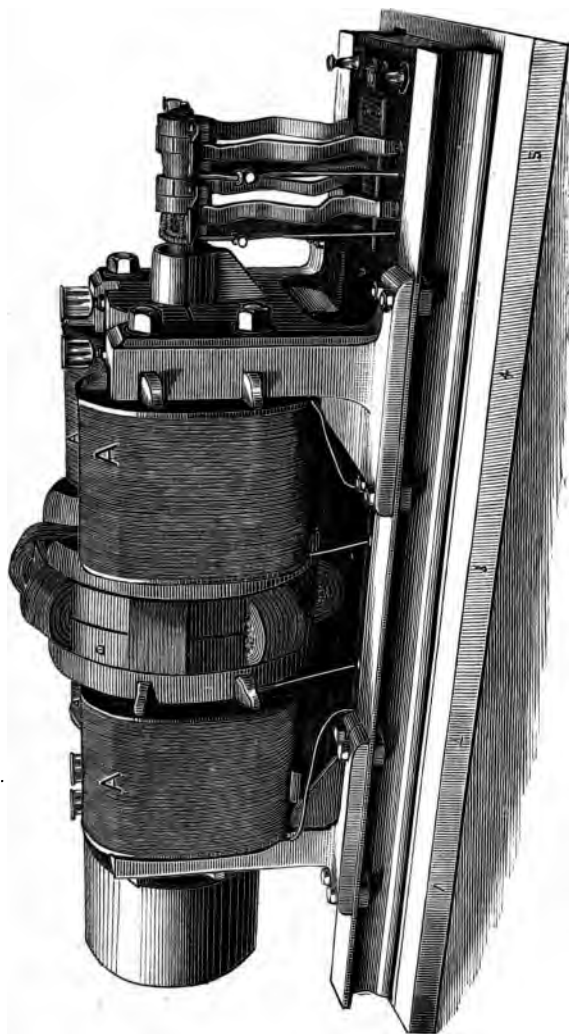


Fig 70.—Brush's Dynamo Machine.

position of the field-magnets is altogether different from that adopted by M. Gramme. The 4 flat exciting coils, A A, envelope cores of iron furnished with extended polar pieces, which altogether embrace a large proportion of the active surface of the armature. The magnetic system may be regarded as two electro-magnets, with similar poles opposite, and excited by a current passed through the coils, which are connected up so as to form one circuit.

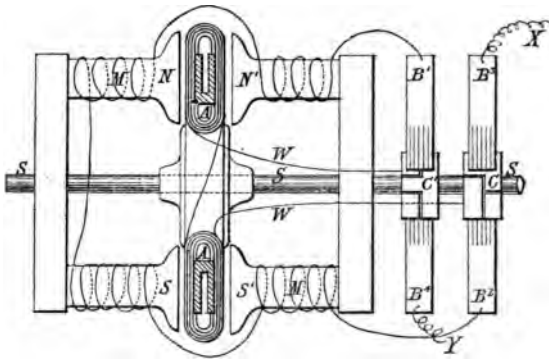


Fig. 71.—Diagram of Brush's Machine.

In Fig. 71 the position and relationship of the field-magnets and armature will be rendered still more intelligible. In this view M M represent the soft iron cores of the electro-magnets, and N S their extended poles. The portions of the framework of the machine connecting the two cores of each magnet are of iron, and we have, therefore, a pair of what is familiarly known as horseshoe electro-magnets. The arrangement of the wire represents the course of the current around each of the cores.

It will be particularly observed that one of the extremities of the wire coils is connected with the collecting "comb" B^1 and the other with B^2 . By these means the currents from a certain number of the helices of the armature are made to flow round the field-magnet coils, and those from the remain-

ing helices are utilized for external purposes. In the machine itself the collecting "combs" $B B$ are adjustable in relation to the line of maximum current upon the commutator.

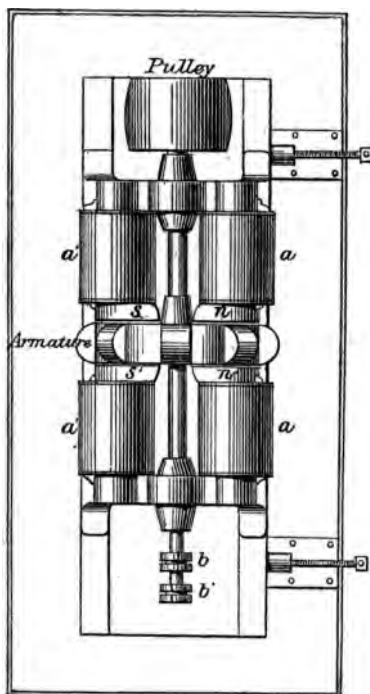


Fig. 72.—Plan of Brush's Machine.

The Figs. 72 and 73 show a plan and end elevation of the machine. The disposition of the polar extensions of the field-magnets is represented at $n s$, $s^1 n^1$ (Fig. 72), $a a^1$ being the exciting helices of the mag-

nets; $b b^1$ represent the two parts of the commutator and its arrangement upon the free extremity of the shaft. In the diagram, Fig. 74, is shown the angle at which the collecting combs

are placed in relation to the shaft and commutator.

The total resistance of the 16-light machine is from 10 to 11 ohms; of this the field magnet helices contribute 0.625 ohms each, and the armature helices about 1.5 ohm each, 6 of which are in circuit at the same time. The brush or commutator contacts increase the resistance of the machine while in action.

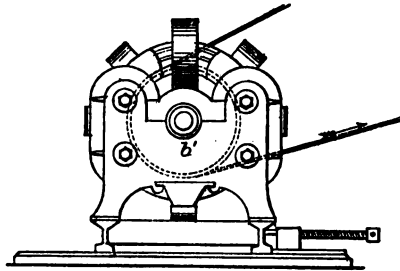


Fig. 73.—End Elevation of Brush's Machine.

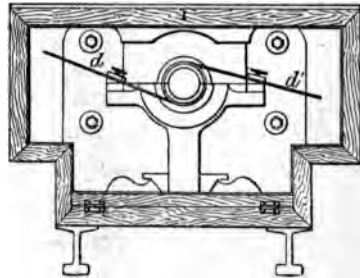


Fig. 74.—Angle of Combs in Brush's Machine.

WEIGHTS, DIMENSIONS, AND LIGHT-GIVING POWER OF THE BRUSH MACHINES.

No. of Machine.	Weight in lbs.	Length in inches.	Width of base. Inches.	Height in inches.	Speed re-quired.	H.P. re-quired.	No. of arc lights.	Power of each light. Candles.
2	260	35	11 $\frac{3}{4}$	14	1,100	2	1	1,500
3	400	39	13 $\frac{1}{4}$			4	2	1,500
4	550	42	14 $\frac{1}{4}$	18	1,050	4	3	2,000
5	1,150	51	16 $\frac{1}{2}$	22 $\frac{1}{2}$	900	8	6	2,000
6	1,500				850	10	10	2,000
7	2,500	68 $\frac{1}{2}$	21 $\frac{1}{4}$	28	800	19	16	2,000
8	4,800	88 $\frac{1}{2}$	28	30	700	45	40	2,000

Edison's Machine.

A general view of this machine is given in

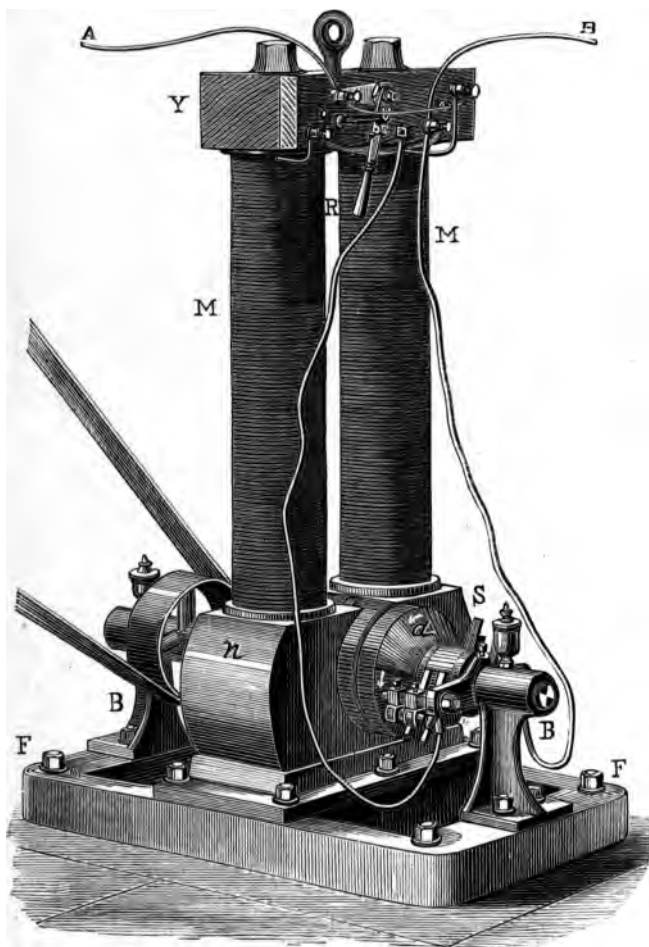


Fig. 75.—Edison's Machine.

Fig. 75. In a large machine of the same kind the

arrangement of the field-magnet is horizontal, but the essential features of the apparatus remain the same. It consists essentially of a powerful electro-magnet with two limbs, *M M*, connected together magnetically by the soft iron yoke-piece, *Y*, and terminating in the two massive cast-iron polar extensions, *n s*. These are insulated magnetically from the massive base-plate, *F F*, which is of cast-iron.

The distinctive features of the apparatus lie in its armature, *a*, which is mounted upon a shaft working in bearings, *B B*. It is difficult to render the construction of this armature clear by means of a diagram. It consists, Fig. 76, of a core of iron, composed of a large number of soft iron discs, *d d*, insulated magnetically from each other and from

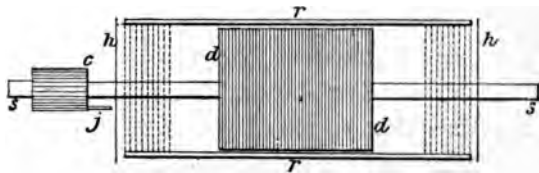


Fig. 76.—Diagram of Edison's Armature.

the axle, *s s*. These discs are bolted together, and form essentially a solid mass of soft iron rotating with the shaft. So far the construction is quite simple. In order to comprehend the arrangement of the other portions of the armature, the reader may conceive a solid iron cylinder, having coiled upon it, longitudinally, a complete envelope of thick copper wires, wound, not only along its sides,

but over one of its ends. We may imagine the free extremities of these convolutions to be connected to the collectors of a commutator, and this conception will give a good idea of the armature in Edison's machine. We may indeed carry the conception even further, and compare Edison's armature with that of Siemens, in which wires are coiled in sets around the exterior of an iron cylinder. But in Edison's armature the wires are represented by thick copper bars, two of which are represented at rr in the diagram. A considerable number of these bars is arranged parallel to the axis of the core, and we may regard them as representing, essentially, the parallel wires of Siemens' armature. The lines h and h represent two of a series of copper discs, insulated from each other and from the shaft. The spaces filled with transverse dotted lines are occupied by these copper discs. Each disc has two extensions, or "lugs," at opposite diameters, to receive the ends of the copper bars. The real function of these plates is to form connections between each pair of diametrically opposite parallel copper bars, and the real effect of the whole arrangement is to enclose the iron core in an envelope of metallic conductors of exceedingly low resistance. At the end of the armature next to cj , each of the copper discs has extending from its central portion a copper "tongue," or junction, in the direction of the commutator, cj , and parallel to the axis. These copper tongues are made to slip into the longitudinal channels of the commutator,

and therefore serve as the commutator plates or contacts, each tongue, *j*, having its proper groove. It is almost needless to mention that all portions of the armature are carefully insulated; for this purpose talc and other thin insulating substances are employed. The completed armature is enveloped in a covering of paraffined canvas or other suitable material, in order to exclude dust, which would otherwise clog up and short-circuit the spaces between the copper bars and discs. When the armature is of large diameter, it is protected from the effects of centrifugal force by a winding of fine steel wire.

The field-magnet of the machine is excited by a portion of the main currents being shunted into it. For this reason the coils upon its limbs are of comparatively high resistance. The balancing of current to work takes place in this machine in the same manner as has been explained in reference to Siemens' machines. The electromotive force of the machine is about 110 volts.

The large machine employed in the incandescent electric lighting of Holborn Viaduct, London, is combined upon one massive cast-iron base, with a Porter-Allen high-speed engine connected to the armature shaft direct, the whole weighing 22 tons. The field-magnet is composed of two separate sets of limbs attached to heavy cast-iron polar pieces. The coils surrounding the limbs of this magnet are connected together in two series, each of which presents a resistance of 12 ohms. The two series

are connected in parallel circuit, so that their resistance together, being half that of one of them singly, is reduced to 6 ohms. The gauge of wire employed is Brown and Sharpe's No. 10.

The armature is built upon a steel shaft 6 inches in diameter. Over a core of soft iron discs is arranged the system of copper bars, 106 in number, of an average length of 52 inches, and $\frac{1}{2}$ inch in thickness. These are connected together by means of 53 copper discs, each $26\frac{1}{2}$ inches in diameter, after the manner previously explained. The parts of the armature are insulated by means of ebonite and mica. Every alternate rod in the armature is connected by a radial copper bar with the contact blocks of the commutator, of which there are 53. The commutator cylinder is $12\frac{3}{4}$ inches in diameter. The resistance of the armature from brush to brush is only .0049 of an ohm. The field-magnet is excited by a portion of the current on the shunt principle before spoken of. The Porter-Allen engine is of 40 nominal H.P., with cylinders 11 by 16 in., the steam being cut off at about half-stroke. The speed is 350 revolutions per minute, and the indicated H.P. is about 125. This great machine is capable of maintaining 1,000 of the Edison incandescent lamps, each of 16 candle power. The apparatus, as employed at Holborn Viaduct, yields an illuminating effect of 128 candles per H.P. In the great installation of the Edison system in New York, 12 of these great machines are used, developing similar effects.

The current evolved by the armature of the Edison machines is controlled, so as to be made great or small, by means of resistances inserted in or withdrawn from the exterior portion of the field-magnet circuit. These generally consist of copper or iron wires, coiled around frames, with arrangements for including a greater or less length of wire in the circuit, as required by the circumstances of each case.

The Wallace-Farmer Machine.

Fig. 77 is a view of this machine. It is of American manufacture, and has been much spoken

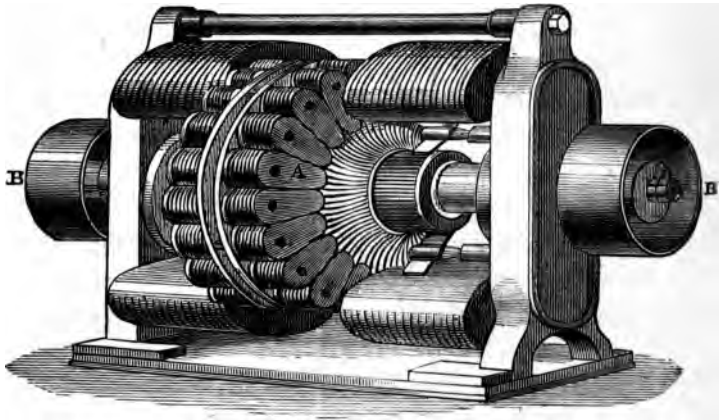


Fig. 77.—Wallace-Farmer Machine.

of as that formerly employed by Mr. Edison, of Menlo Park, in his first electric light experiments.

The inducing magnets are flat in shape, and are two in number, attached to the frame. This ma-

chine is in reality only an extension of the principle upon which Clark arranged his two-bobbin armature.

Instead of the armature being a straight bar, carrying a pair of bobbins and cores before the magnet poles, two iron discs about an inch apart are employed, studded all round with bobbins and cores, one set to each disc. The poles of the inducing electro-magnet are thus as far apart from each other as the diameter of the bobbin wheel, or nearly so. There are four collecting brushes and two commutators upon the axis where the currents are taken off. The bobbins may be coupled up for tension or quantity. The shaft is carried through, and runs in bearings in the side uprights. Each of the discs may be driven separately, by means of one of two pulleys, BB^1 , or they may be coupled together, to be driven from one of the pulleys.

The electric impulses given off by each bobbin are of necessity of very short duration, but as the speed is high, these combine to give rise to a continuous current. The construction presents a large surface to the cooling effects of the air, but this also introduces a disadvantage, as the various parts act as a fan, which causes the air to act an appreciable part in consuming the driving power necessary. The high speed—800 per minute—causes the armature wheel to give out a humming sound when in motion, proving the fan-like action of the bobbins.

Heat is developed in such quantity that, despite

the cooling by air, sealing-wax may be melted upon the armature wheel when the machine has been some time at work.

Variouly different arrangements of the magnets, connections, and commutators may be made in this machine. The practice, however, is to oppose to each other the poles of the magnets, so that the poles of the bobbin cores change polarity during every half-revolution. The wires are connected up so as to pass the currents from the coils, after they have been commuted to one direction, through the inducing magnets, as in other forms of dynamo-electric machines. The collecting points are arranged similarly to those in Gramme's machine, the wires being connected to metallic sectors insulated from each other. Appended are some useful particulars of the wires employed and the work done. The machine is made in two sizes :—

	Copper Wire on Armature.		Copper Wire on Magnets.	
Large Wallace.	0.42 in.	50 lbs.	.114 in.	125 lbs.
Small „ .	0.43 „	19 „	.096 „	41 „

Work.—The weight of the large Wallace machine is 600 lbs., of the smaller size 350 lbs. The armatures or bobbin wheels revolve, 800 revolutions in the large per minute, and 1,000 revolutions in the small machine. The horse-power required is, for the large $4\frac{1}{2}$, and $3\frac{1}{2}$ for the small machine. The illuminating power, in standard candles, is, for the large machine, 823, and for the small, 440. Or,

per horse-power, 113 for the smaller machine, that given by the large machine not having been determined.

Figures concerning the consumption of carbon by these machines are given by the committee appointed by the Franklin Institute to test them, but they are really of little value, since one quality of carbon is known to burn as fast again as another. The diameter of carbon rods used for the larger machine was $\frac{3}{8}$ in., and $\frac{1}{4}$ in. for the smaller.

The Bürgin Machine.

The field-magnet of this machine is arranged in the same way as that of Siemens' continuous current machine.

In the space occupied by the Siemens armature is placed an armature composed of several circles of soft iron wire or tape wound with several helices of insulated wire, forming in all (in the 3-light machine) 48 coils, each composed of wire .065 inch in diameter, and 48 feet in length. The weight of the wire is 25 lbs. The soft iron core of each of the rings forming the armature system, is supported by arms radiating from the shaft. The coils are connected together to form an endless helix, as in Gramme's ring, and junctions are taken from the connection points to the commutator plates, of which there are as many as there are junctions or coils. The electro-magnet carries four flat coils of wire, each 750 feet in length, and having a total weight of 140 lbs. The resistance

of the armature is 1·6 ohm; of the magnet, 1·2 ohm, giving a total resistance between the terminals (when the machine is so wound that all the current flows around the magnet) of 2·8 ohms. The electromotive force developed by the machine at its normal speed (1,500 revs.) is 195 volts, and when the speed is increased to 1,600 revs., 206·5 volts, through a resistance, in both cases, of 13·16 ohms. The velocity of the mean diameter of the armature coils through the magnetic field is, at 1,500 revs., 2,550 feet per minute. The greatest current the machine can develop with safety is about 25 ampères. The electromotive force is found to vary directly with the speed between 1,000 revs. and 1,700 revs.

The total length of the machine over shaft is 2 feet 10 inches; height to terminals, 1 foot 1·5 inch; width, 2 feet 4 inches; weight, about 6·5 cwt.

Some interesting experiments were made with the Bürgin machine by Messrs. Crompton and Co., at King's Cross Station, in July, 1881. It was found that, with the machine running at 1,480 revs. per minute, with 3 arc lamps in circuit, a current of 16 ampères was evolved at the expense of 1·49 H.P. per lamp. With improved arrangements later on, the machine gave, with 1,140 revs., a current of 14·8 ampères, at 1·37 H.P. absorbed per lamp. It was found, by means of balancing by iron wire, and measuring that by Wheatstone's Bridge, that, with 3 lamps in circuit, the resistance was 9·36 ohms. Carré's carbons of 13 millimètres diameter were used. The total resistance was

13.26 ohms, namely, that of lamps, 9.36 ohms, leading wires, 1.1 ohm, machine, 2.8 ohm. Deducting 1.5 ohm as the resistance of each lamp (carbons, connections, etc.) the resistance offered by the voltaic arcs was 8.76 ohms, or about 65 per cent. of the whole. Therefore, about 65 per cent. of the horse-power appeared in the arc as light.

The following notes on various other machines may be of use to those of our readers who wish to obtain more detailed information on the subject :—

Fitzgerald's Machine.

Mr. Fitzgerald has obtained patents for a machine based upon the Gramme principle, and including many points of excellence. It will be found described and illustrated at some length in the *Electrician* of September 25th, 1880.

Ball's Machine.

Two types of this machine were shewn at the Paris Electrical Exhibition of 1881, the one simple, the other compound. The armature of the simple machine was composed of 6 horseshoe-shaped helices, similar to those of Siemens' alternating current machine, the coils having no cores. They are connected together so as to form one continuous ring, and at the points of junction connections are taken leading to the commutator.

Hopkinson and Muirhead's Machine.

This remarkable development of the principles of the dynamo-electric machine was exhibited at the Exhibition of Paris, 1881. It will be found described in the *Electrician* of September 24th, 1881.

Fein's Machine.

This apparatus is based upon the principle of the Gramme machine, with extensions of the polar pieces of the field-magnet, so as to influence the inner faces of the helices of wire coiled upon the armature, as well as the outer faces, as in the Gramme machine. See *Electrician*, July 9th, 1881.

Gulcher's Machine.

This machine bears some resemblance to the Brush apparatus. It will be found described in the *Electrician* of Oct. 29th, 1881.

CHAPTER VII.

GENERAL OBSERVATIONS ON MACHINES.

MEASUREMENT has been made by Dr. J. Hopkinson and by Mr. L. Schwendler, independently, of the energy obtained in the form of current from a Siemens machine as compared with the energy shown to be consumed in driving it, and the result showed that only from 12 to 13 per cent. of the energy is wasted, but as lamps are usually adjusted, only half the energy of the current appears in the arc, or 44 per cent. of the energy transmitted by the strap.

Work to Expect of Machines.

Many machines churn the air to such an extent that a continuous humming noise is produced, and from 1 to 25 per cent. of the total driving power is thus expended upon the air alone. One machine examined wasted 17 per cent., and it is probable that such types of generators would heat to an inconvenient extent were it not for this air-churning.

With regard to the amount of light produced per horse-power this varies considerably in different machines. Experiments were made at the South Foreland by the Engineer to the Trinity

Board, the results of which are given in Sir James Douglas's paper read at the Institution of Civil Engineers in March, 1879. The following are a few of the results obtained.

Machine.		Light produced per H.P. in standard candles, mean of experiments.	
Holmes's	Magneto-Electric		475
Alliance	„		543
Gramme,	No. 1		758
„	No. 2		758
Siemens'	Large		911
„	Small		954
„	Small		1,254

Thus it will be seen that a good machine should give about 1,000 or 1,200 standard candles per horse-power in the electric arc; but the measurement of the light is, in fact, rather a difficult and doubtful matter, owing to the errors caused by the varying position of the carbon points, and the difficulty of obtaining a reliable standard of comparison.

Some of the machines will yield arcs of greater power than that above spoken of and others less; but when the light falls much below 700 candle-power for each horse-power required, it is reasonable to judge the machine as inferior. It will be understood that this is the light ordinarily obtainable from separated carbons in the Serrin or other equally good voltaic arc lamp.

So high an illuminating power will not, in all probability, be obtainable from any lamp of the incandescent type, although incandescent lamps may be found more serviceable on account of their steadiness.

With reference to the light power obtained per H.P. in the case of lighting by incandescence, it may be of interest to remark that in the trial performances of the Farranti-Thomson machine in December, 1882, from 12 to 14 of Swan's 18-candle incandescent lamps were maintained per H.P. consumed. But it is not certain whether every one of the lamps in circuit was raised to its full photometric value. The above number of lamps per H. P. would appear to indicate that it is possible to obtain about 230 candles' light per H.P. consumed by the machine. In the trial referred to the Farranti-Thomson machine absorbed altogether 35 H.P., and maintained from 300 to 320 of the 18-candle Swan lamps in a state of incandescence.

Management of Machines, &c.

Having obtained a machine, the first consideration should be its fixing. A dry and cool place should, if possible, be selected, and the machine should be so fixed that its commutator may be freely accessible. The speed to be given to it must then be considered, and a pulley of such diameter employed as will produce, at the normal speed of the shafting or engine, the normal speed stated as applicable to the machine with full current. Broad, stout, and well-stretched belts should be employed. Powdered resin may be sprinkled upon them if there is a tendency to slipping with ordinary tightness. It is of no use to test these questions while the circuit of the ma-

chine is *open*—the machine must be connected by thick wires either to its lamp or to a coil of iron wire, offering a resistance approximately equal to that of the lamp, or the usual circuit to be employed. It is generally considered safest to have the circuit closed previous to starting the machine.

Now is the time to test the speed, and for this purpose one of the small velocimeters, or speed indicators, generally used by engineers will be found very useful. An engine may run 100 revolutions with the machine at open circuit, and this may fall to 70 on closing the circuit. If there be so great a fall as this, the engine-governor is defective. It may, of course, be necessary to regulate or adjust the throttle valve upon the governor, until the machine gives, with closed circuit, the proper number of revolutions per minute.

It must be distinctly understood that a dynamo-electric machine will give *less* than its maximum current if the outside resistance, in wire or lamp, is not proportionate to the internal resistance of the machine—that is, if the outside resistance is too great, the current set up around the magnets will be small, owing to the resistance, and the machine can only, in such a circuit, produce a small current. If the outside resistance is small—that is, if large short conductors are used, with a proper lamp, the machine will not only give maximum current, but must be controlled by the engine, for upon increasing the speed too much the machine

will heat. These conditions are, however, very different when the machine is excited by means of a shunt, as many machines now are.

Again, *never place the machine at full speed on short circuit.* This is of much importance. If the circuit between the binding screws be closed by a short and thick wire only, all the current will be dissipated in the form of heat *in the machine itself*, and the result will probably be to destroy the machine by burning the insulating covering of the wire. But it is probable that in a machine whose field-magnet is excited on the shunt principle, such a result would be impossible. Never allow an inexperienced person to experiment with the machine. Always see that the exterior portion of the circuit provides some work to do outside the machine. If there is work to do, a light to produce, metal to electrically deposit, water to decompose, electric motor to drive, or large magnets to magnetise, or resistance to overcome in a long, thin wire, *the machine will be kept cool*, and with very high resistance the speed may even be increased.

Cables or conductors may be composed of a No. 8 copper wire, insulated with gutta-percha and tarred hemp, or paraffined cotton only—solid paraffin, melted; but it is usually more convenient to make use of a more flexible conductor, composed of from 4 to 8 No. 16 wires twisted together, and covered with gutta-percha and tarred hemp. If the distance between the machine and lamp is over 50

feet, the thickest conductor should be used, so as to reduce the resistance; and if the distance be small, a thinner conductor will serve. These cables are now obtainable of dealers in electrical machines. They are referred to at greater length in the chapter on "Circuits."

If there is jumping or flickering of the light, the carbons are bad, or the same defect may be caused by the engine not having a sufficiently sensitive governor to keep up a steady motion. If the carbons are bad, there is more need for a sensitive governor, and the engine, however good, will not maintain a steady current.

Dynamo-electric machines, when working upon a voltaic arc lamp circuit, vary much in the strain they impose upon the engine. This variation is mostly due to the difference in resistance presented every moment by the voltaic arc in the lamp. If the engine is not provided with a heavy fly-wheel or a sensitive governor, *always employ one of greater power than is really needed*. Thus, speaking of common engines—perhaps of the agricultural type—if 2 horse-power is necessary for the machine, use a $3\frac{1}{2}$ or 5 horse-power engine; and if another fly-wheel can be fixed to the opposite end of the shaft, let it be done; also see that the governor is quite free to act.

In the case of driving-off shafting, the main look-out is the provision of steadiness in the machine's motion. Large mill shafting, when the revolutions are quite regular, will be found to work

dynamo-electric machines to perfection, as will also a large engine of any kind. It will be observed from this that the dynamo-electric machine *needs steadiness in driving if a steady light be required*. Brotherhood's direct-acting 3-cylinder engine is applicable and very suitable. It is used extensively on ship-board for driving light-giving machines. In such cases it is connected direct to the shaft of the machine, and may by these means be made to actuate at once a Siemens' alternating current machine with its exciter.

Gas-engines answer very well, but they should always be of large size. Otto and Crossley's 8 horsepower gas-engine is one of the best in the market, and is practically as handy in every way as the best steam-engine, but more expensive in working. An engine of the above power will drive two of the small Gramme or Siemens machines steadily, as will also a steam-engine of similar power. Two machines may be driven *off one pulley* by using two belts, one above the other, the machines being placed at different distances from the engine and in a line with the driving pulley.

Water-motors of the small type are at present, at least in towns, much too expensive.

Turbines and water-wheels of different kinds are applicable to the driving of dynamo-electric machines, and where there is a good supply of water at small cost, the expense of illumination in this case would not reach 25 per cent. of that of gas or oil illumination, necessarily of inferior

quality. In this manner Sir William Armstrong illuminates part of his residence at Craigside, near Newcastle, employing over 40 Swan lamps for that purpose.

Heating of Machine in Work.—If a dynamo-electric machine should heat to any inconvenient degree within the first two hours of working, there is something wrong either within the machine or in the lamp. If the lamp is adjustable as to distance of carbons, it will be well to increase the length of the arc, which will reduce the heating. A machine that heats much is not properly constructed, and may be improved by taking a layer of wire off the electro-magnet. If the heat rises so high—very near to the electro-magnet, or upon its body—as to melt sealing-wax, it will be wise to stop working and to increase the outside resistance; and if it should heat with the ordinary external resistance in circuit, the machine should be condemned. A machine *should*, however, heat very rapidly when upon short circuit; if it does not, it is not of much value in the production of light. Care must be taken that the insulation be not injured in an experiment of this kind.

Steadiness may be tested in various ways. Perhaps the most generally applicable test is a Bell telephone. Pass the current, at full speed of machine, through about 500 feet of cable, or 100 feet of stout iron wire. Cut 5 feet of insulated wire, and bind it to the main wire by a cord, fastening its ends on the screws of a Bell telephone.

Currents corresponding to the impulses (if any) given off by the machine will thus circulate, *by induction*, through the telephone coil. By placing the ear to the telephone mouthpiece, any augmentation or reduction of working power may be noted by the noise in the telephone becoming greater or less; and if the machine does not give a steady current, the fact will at once be noted. Sudden rushes, ending in a slower succession of impulses—as whir-r-r-r, whir-r-r—will, in all probability, be due to want of sensibility in the driving-engine's governor. With a constant resistance the current should be almost perfectly steady. If there be an unsteady light with a steady current, it will be due to a fault in the lamp, or more probably to bad carbons, or both. The light should slightly increase in brilliancy as the carbons become shorter, in the case of rod carbons like those used in the Serrin lamp.

Commutators, or Contact Brushes.—Almost every machine has a pair of contact or collecting brushes, to connect the armature wires through the electro-magnet wires to the external part of the circuit, as in the Siemens machine, where one of the collectors is connected to one extremity of the field-magnet helices and the other to the exterior resistance, except in shunt-wound machines. Or it may be, in some constructions, that there are 4 brushes pressing upon the collecting axis—2 for the outside circuit and 2 for the electro-magnets.

But contact brushes, for whatever specific pur-

pose, are the same in all machines, although their shape and the material may be different. As far as experience has indicated, the best brush in use would appear to be a copper one; it is generally composed either of sheet or wire copper. The sheet employed is cut into thin narrow slips, and as the material is thin, a bundle of from 10 to 50 is employed. Such brushes press upon the collecting drum in a slanting position, and all the free ends of the bundle are arranged in a slant, or to form an angle of about 20 deg. with the brushes' plane. In the Brush machine the collectors are "combs" formed of hard sheet copper.

Copper-wire so used is rendered hard by repeated drawing, and the bundle is placed in most cases with the ends equal, and right under or above the axis or at the sides, to right and left, as may be required.

The object of all collecting arrangements is to take off the currents just at the point where there is least sparking, and also to do this with little pressure, because heavy pressure causes much wear and tear of the commutating cylinder. When commutators and brush-holders are adjustable round the collecting drum, care must be taken to so fix them that the loss by sparking is reduced to its minimum, and when this spot is found, the points of maximum current will also be under the brushes. To adjust the brushes, set the machine in motion, and make one just touch the axis, then screw up the other until a moderate pressure is given,

and the sparking almost disappears. Adjust then the opposite one in the same way; but one brush will be found to set off a greater number of sparks than the other. What is really required is *the minimum of pressure with the minimum of sparking*. Use common oil, or preferably tallow, free from grit, upon the commutating drum. Shift and recut the brushes when they become worn or burnt.

The following directions apply to the Brush machines:—

It will be found that when the brushes are rocked too far forward in the direction of rotation of the commutator, the sparks will quite disappear, but the lights will go out occasionally, and each extinction will be attended by a few long sparks on the commutator. This may at once be corrected by rocking the brushes in the opposite direction a short distance. If the brushes are rocked too far there will be much sparking and a diminution of light in the lamps, and occasionally extinctions will take place similar to those which occur when the brushes are rocked too far forward. The brushes should be rocked as far forward as possible without causing the occasional extinction of lights. When too much oil is used on the commutator, sparks will be produced similar to those which appear when the brushes are in the wrong position; hence due care must be taken to put only just sufficient to prevent cutting of the commutator segments. After the machine has been run awhile and has become warm, a slight re-adjustment of the brushes

is sometimes advisable, and a little experience will soon enable the attendant to determine the exact adjustment that will produce the best effect.

When the brushes are much worn they must be clipped off squarely at the worn end, and moved up to the same position as before.

Regulators of Current.

Many attempts have been made to invent or introduce some device by means of which currents from dynamo-electric machines might be automatically regulated or governed, as the steam supply is controlled in steam-engines.

The electric light without a steady current is very unsteady, and as constant strength of current depends in a great degree upon the motor itself, it is found that common steam-engines, unless of greater power than is really required, are not the best for the working of electric-light machines. In the earlier attempts at electric lighting there existed a want of perfection at three points concerned in the production of the electric light. The engine seldom had a sufficiently sensitive governor; the lamp was unsteady on account of various defects in the carbons; and the machine itself was entirely without a means of regulating its supply of current to the exigencies of the exterior portion of the circuit.

These faults combined did much to render the introduction of electric illumination difficult where a perfectly steady source of light was required.

Staite and Edwards patented, so long ago as 1855, an electric regulator based upon the heating and expansion of metals by the current to be regulated. The metal used was platinum, in the form of wire; this was attached to a lever amplifying its movements, and the lever in turn moved a resisting coil of wire. This coil was a common naked helix, having some elasticity, and the action depended upon more or less turns of the wire being pressed together, so diminishing the resistance or augmenting it as the expansion and contraction of the platinum wire demanded. This idea, beautiful in itself, is really the origin of some of the regulators used to-day, and the same principle was employed by Mr. Edison in his attempts to construct a self-regulating lamp. This device was, however, to a great extent a failure, from various causes considered under the description given of the lamp.

Dr. Siemens has constructed a regulator worked by the expansion and contraction of a strip of platinum or steel; but the apparatus, so far, does not appear to have been practically applied. The action is somewhat similar to that employed in Messrs. Staite and Edwards' device. The resistance coils used are put in or out of circuit by the amplified movements of a lever.

Siemens' Safety Regulator.—Fig. 78 is a view of the working parts of one of the best regulators yet put into use generally. It is issued by the makers of the Siemens machine.

A is an electro-magnet in the circuit of the

machine and lamp; B is a contact point in connection with the main circuit through the resistance coil shown only. Normally, the electro-magnet attracts the armature, and the current passes right through the instrument without experiencing

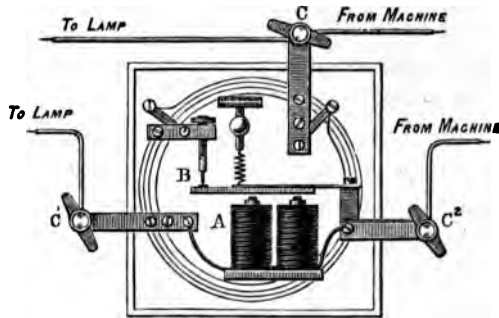


Fig. 78.—Siemens' "Circuit Regulator."

appreciable resistance; but should the lamp by any accident go out or break circuit, the machine cannot be damaged by the engine racing when the load is taken off. The resistance coil is equivalent to that of the lamp when burning, and to keep it cool it is immersed in a small tank of water in the base of the regulator.

It will at once be seen that this is far from being a regulator, in the true sense of the word, because it is only useful in the case of any *excessive* change in the current strength. It is, however, no doubt a valuable adjunct to the dynamo-electric machine, as much harm cannot be done to either engine or machine when this is in circuit. It is joined up in the usual way, by cutting the conductor near to the

machine, and connecting one end to C, and the other to the same point, but, of course, on the opposite side of C, so that when the machine is working the current may pass direct to the lamp. The other connections, C¹ and C², are made by cutting the remaining conductor, and joining up as shown. The instrument may be regulated for strong and weak currents by the antagonistic spring screw and by the contact screw.

In all regulating apparatus intended to regulate the current by actual breaking of the circuit, a very great objection is introduced by the extra current sparking at the contact. A word of explanation as to what this really is will not be unnecessary.

When two *short* wires are attached to any electric source, such as a voltaic battery, their ends touched and then separated, an exceedingly feeble spark only is noted; but when the wires are *long*, a large spark of great brilliancy is produced, and when the same wires are coiled up, especially around iron, the spark is still further increased in size and length. This is usually spoken of as the "extra" current spark, and is due to electro-magnetic induction.

Any regulator, then, depending upon actual breaking of circuit for its action, must so far be very inefficient, because no contact points yet discovered or tried will withstand the burning power of the electric spark. Edison's lamp was intended to work by the constant making and breaking of the circuit, and as no contact points could stand *this* for over a few minutes and retain their sensi-

bility, the idea was thoroughly impracticable, and is only of use in the case of Siemens' check just illustrated.

Dr. Siemens also described, in January, 1879, a regulator based upon the curious property, discovered by Hughes and Edison, that carbon when under pressure will conduct better than when free from pressure. Thus Siemens proposed to place a number of carbon discs in an insulating tube, pass the current through them, and by means of a variable expansion of platinum, as in Staite and Edwards' apparatus, to vary, by more or less pressure, the conductivity of the carbon series. There is no positive break here, and something remains to be done with the idea.

But recent advances in the application of the electric light would appear to indicate that by different methods of connection within the machine it may of itself become its own regulator.

The method employed at present is chiefly based upon the principle of exciting the field-magnets of the machine by a portion of the armature current only, instead of, as formerly, the whole of the current. By these means a shunt-wound machine, as it is termed, becomes automatically powerful or feeble to meet the exigencies of the exterior resistance. This important method of exciting the field-magnets was published in a paper read by Mr. Alexander Siemens at the Society of Telegraph Engineers and of Electricians, in March, 1880. It is spoken of further on.

CHAPTER VIII.

ELECTRIC LAMPS AND CANDLES.

AN electric lamp is the apparatus at which the electric current is actually converted into light. Generally it consists of an arrangement of two carbons for forming the electric arc between them, but endeavours have also been made to obtain light by the mere heating of a short piece of carbon or metal, and have been so successful that these incandescence lamps are coming into general use for both interior and exterior lighting.

Arc Lamps.—When two pointed sticks of carbon attached to the two poles of a source of electricity, such as any of those previously described, are touched together, a current will pass, and the carbons may then be separated a certain distance without interrupting the current, which is carried on by the intermediate air heated by the current, and an exceedingly brilliant light, which is termed the *voltaic arc*, will be produced between the carbons.

Particles of burning carbon are projected from one carbon to the other and a portion of the light is attributed to this flow of burning matter, but the greater portion is due to the incandescence of the

carbon, or to a conversion of electric current into light, as inexplicable as that produced in a spark discharge between two conductors, or in a flash of lightning.

The positive carbon, or that *from* which the current is generally assumed to flow, is, in voltaic arc lamps, consumed very fast, and becomes hollowed out, forming a crater, while the negative or receiving carbon is acted upon very slightly, and becomes pointed. Carbon rods may burn at the rate of about 5 in. per hour, according to their size, and as they consume away must be fed up to each other, in order to continue the light. This was formerly done by hand, but now it is effected by such perfect automatic lamps that the light is not only perfectly steady, but needs no attention whatever for several hours together. It is no difficult matter to feed carbons by hand, by means of a screw attached to one of the pencils, and for taking photographs by quick-acting plates this will answer very well, but a lamp is the only satisfactory means by which ordinary carbon rods can be burned for general purposes.

In another class of lamps the carbons are kept actually in contact. Thus, if pointed rods of carbon, or one pointed and one flat carbon or piece of copper, are attached to the poles of a source of electricity, and the two poles are brought together, a bright light will be produced at the point of actual contact, and will remain practically steady as long as the carbons are kept together.

This principle is adopted in several different kinds of lamps. The light is partly due to the incandescence of the carbon and partly to the voltaic arc produced round the point of contact. These devices are sometimes spoken of as "*semi-incandescent* lamps."

Another method is to join the two extremities of a powerful source of current by a thin strip or coil of some difficultly fusible metal, or by a filament or thin pencil of carbon itself. In either case the resistance of the material, it being small in bulk, causes the passing energy to heat it to a point past white heat, when it emits a light of considerable brilliancy. This condition is known as electric incandescence. The light emitted may be regarded as a *heat light* rather than as an electric light.

Such lights are not so brilliant as those produced when the carbon pencils are actually separated.

As early as 1843 experimenters were at work upon this useful application of electricity, and the celebrated Foucault produced the light from rods of gas carbon and a battery of Bunsen cells. Previously to this wood carbon was frequently used, and among others by Sir Humphry Davy, at the beginning of the present century, when he produced his (and the first) voltaic arc over the Royal Institution, from a battery of 2,000 cells.

It was soon found that the electric light was not only independent of air or oxygen for support, but possessed the properties of sun-light in showing all

colours as they appear to the eye in sun-light. It was also found that no vapours, smoke, or appreciable (diffused) heat were given off by it, and that its chief peculiarity was exceeding brilliancy difficult of diffusion.

Fig. 79 is an enlarged view of the carbon points as they actually appear when their image is thrown upon a screen for examination. P is the positive or feeding end, and N the negative or receiving. The nodules observed chiefly on the lower carbon are impurities in the substance, which melt and stick to the points. The light itself is not only produced by electricity itself, but by millions of highly incandescent particles carried from the positive to the negative carbon.

The stronger the current under these conditions the more powerful the light, and the greater distance will the carbons admit of being separated without extinguishing the light.

The power of electric light is usually expressed in terms of the standard candle, and varies from, say, 10 candle power to 16,000, above which it has not as yet been found generally economical to go in one centre of light.

It would appear that about the year 1845 the first patents were applied for in electric lamps or burners. The names of King and Wright are the

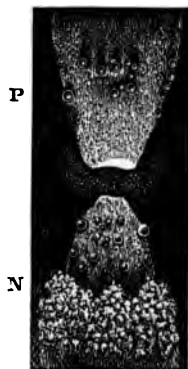


Fig. 79.
Carbon Points.

first concerned in the invention of patented apparatus of this kind. King's patent was for an incandescent burner of platinum, and Wright used revolving discs of carbon. Probably the best attempt at obtaining a steady light shortly after this date (1846) was that of Staite and Edwards, who made a lamp in which two rods of carbon were pressed together at an angle upon some badly conducting substance. Greener, Staite, and Petrie then produced lamps of various kinds, and in 1848 a self-regulating lamp was made by Foucault.

It will be unnecessary to give particulars of all the numerous, and often useless, pieces of electric lamp apparatus invented since 1845; we shall therefore describe only those lamps which have of late years been most extensively used, or otherwise of practical interest.

Carbons.

As has been before stated, rods of charcoal were first employed as the points in the production of electric light. This was found to burn too fast, and is too easily split, although, when well prepared, it may be used in some cases.

The scale of deposit found in the interior of gas-retorts after use was found to be well adapted for the purpose. This substance is inexpensive, as it may usually be obtained for the trouble of carrying away; but it is not, in its crude state, well suited to the production of steady light. It is very impure, containing various foreign earthy matters,

sometimes metals; but silica is the most troublesome constituent, as it is more difficult of fusion than the pure graphite. A good gas carbon is of a fine texture, and a clear grey colour. It is very difficult to cut or shape, on account of its hardness.

Many attempts have been made since 1846 to obtain a perfectly pure powder of graphite or other substance suited to the steady production of light.

Staitt and Edwards' Carbons.—These were in use for a considerable time before other inventors came into the field. They were made by finely powdering the best gas carbon, mixing with a little sugar syrup, kneading and compressing in the shape of rods. They were then gently heated and saturated with a strong solution of sugar; they were then heated to whiteness, and were found to burn with tolerable uniformity in good lamps. The same method, with the substitution of tar for the syrup, and the addition of ground charcoal, was patented by Le Molt a few years later.

Archereau's Method consists of mixing with the ground and selected graphite some magnesia, which is supposed to render the light more steady.

Carré's Carbons.—These were for many years the standard carbon rods in use. He mixes with the substance certain proportions of potash and soda, which slightly lengthen the arc and add to its brilliancy. Good carbons are made from the powdered carbon, lamp-black, and syrup of cane-sugar, with a little gum. The proportions may vary, but the following are recommended:—

Carbon powder, 15 parts; calcined lamp-black, 5; syrup, 7. These substances are perfectly mixed, with a very little water added, when the mass is well pressed and rounded by being passed through a draw-plate. The rods are then baked dry, and while still hot are immersed in a solution of cane-sugar or a strong syrup, which is pressed into their pores, and they are then again heated to a high temperature. Carré would appear to prefer coke-dust, as found in retorts, to ground carbon.

Many attempts have been made to improve the conducting power and steadiness of carbons by coating them with metals. They are almost all failures, except the method of coating with copper. Lamps are now in use by which the current is not caused to travel the whole length of the carbon. A great many mixtures have been tried both inside and outside the carbons.

Carbon rods frequently crack and split at the points, so extinguishing the light for an instant. This usually results from the use of inferior carbons, and by employing them of too small a body for the current. Carbons should be selected to suit the current to be passed through them. If they are irregular in composition they will crack, and whether regular or not they will crack when the current is too strong for their size. M. Gramme mixes with the powders nitrate of bismuth, which is of use in preventing cracking and augmenting the steadiness and power of the light.

In arc lighting it is important to observe that the

arc should be maintained as large as the electromotive force of the electric source will permit. The length of the arc may vary from 1 millimètre (about the $\frac{1}{25}$ th part of an inch) to several millimètres. When the arc is too long, the light will become of an uncertain and flaming nature, and may be easily extinguished by any diminution in the current strength. When the arc is too short, the light produced will be only partially diffused, and may be quite shut in upon every side by "mushrooms," or excrescences around the points, particularly the positive point. The hissing noise made by the arc generally indicates the presence of impure carbon, or too short an arc. The carbon rods should be as large as the current from the electric machine will easily consume. If the rods are too thick, only a portion will be consumed at once, and not the whole sectional area of the rods. If the positive carbon should burn into several craters, it is too large. If the carbons are too thin, they will be unduly heated throughout their length, and will offer great resistance.

Lamps with Automatic Regulators for Arc.

When the electric light is obtained by carbons separated a certain distance so as to produce the voltaic arc, the carbons consume away, and thus increase the length and electric resistance of the column of heated air between them. As the resistance increases, the current diminishes; this decrease of current again lessens the heat

of the column of air which has already been lengthened, thus the rapid increase of resistance soon causes the arc to cease altogether suddenly. To overcome this the carbons must be kept constantly at the same distance apart. At first this was done by hand adjustment, but this was evidently an incomplete arrangement, and the attention of electricians was turned towards some means of overcoming the difficulty by mechanism that should act automatically.

In 1846 Staite used clockwork to bring the carbons together, the rate of the clock being previously regulated to suit approximately the consumption of the carbons, but this was not found to answer, as the carbons burn irregularly.

Attempts to make the decrease of current itself adjust the carbons were soon made. It is difficult to give the date of the earliest invention for this purpose, but Staite as early as 1847 patented a lamp in which the clockwork for moving the lower carbon is controlled by a movable weighted soft iron core acted on by a hollow electro-magnet.

Perhaps the Foucault and Wilson lamps were amongst the earliest. But the author cannot pretend to place the various lamps in chronological order, but commences with the Serrin lamp, as a good type of the clockwork or self-regulating kind.

The Serrin Lamp.

Fig. 80 is a view of the interior of this lamp. A is an electro-magnet; B its armature,

which, when the current passes, is attracted, and through its connection with the sliding bar of the lower carbon, E, pulls it down, and makes the separation. The apparatus is put in motion, not by a spring, but by the weight of the upper carbon holder constantly tending downwards, which pressure communicates motion to the train of wheels by its toothed rack, as shown. The rate of descent in the upper carbon with its rack is, of course, regulated by its setting the wheel train in motion, which brings a check, connected to the left side of the lower carbon holder, to bear upon the arms of the radial fly-wheel lowest in

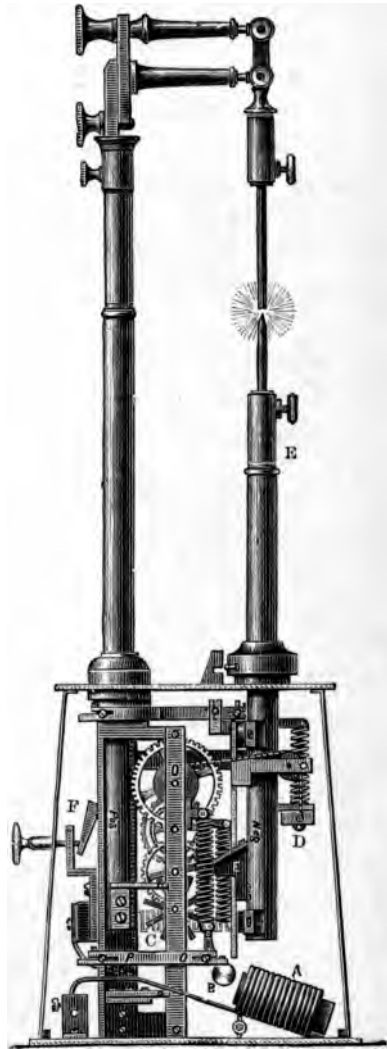


Fig. 80.—Serrin's Lamp.

the train of wheels. This locks the length of the arc until from burning away the current becomes weak, and the armature is allowed to go upwards with its lower carbon holder. This it is enabled to do by the springs constantly pulling it away from the magnet. When the lower carbon can thus move upwards, the upper, its wheel train being free, by the check being taken off the radial fly, falls until the current is strong enough to again pull down the lower holder and to again bring the check to bear upon the radial fly, thus locking the distance. F is an adjusting screw, and the two upper screws are for the same purpose. This lamp is singularly efficient, and may be set in action by the most ordinary workman. It will take any length of carbon rods up to about 12 inches.

Archereau's Lamp.

Fig. 8r represents a lamp invented by M. Archereau. It is very simple in construction and action, and forms one of the best regulators for short periods in use.

The author can especially recommend this form of lamp to the notice of amateurs, or those requiring a simple regulator, easily managed for short periods.

It consists of a bobbin or solenoid of No. 12 silk-covered wire, composed of one layer, or two at most, for weak currents, A; having within it a column of metal, B. This cylinder is of soft iron. Its upper end, B, carries the lower carbon rod, which

is fastened by the set-screw shown. The connection to this coil of wire is from the binding-screw to one extremity, while the other end of the coil has soldered to it a thin copper spring, pressing gently upon the interior column. The current thus passes to the lower carbon, while the other connection is made to the metallic upright at D. This metallic pillar may be of brass, and carries a right-angle arm, to which the upper carbon holder is attached, as represented. A counterpoise weight, C, is supported by a cord, which

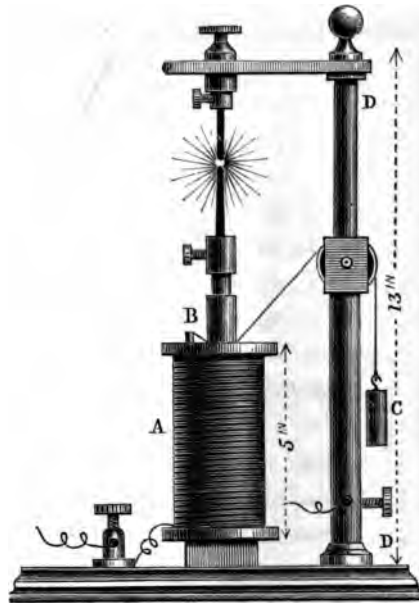


Fig. 81.—Archereau's Lamp.

leads over the central pulley, and, passing under the lower extremity of the metallic column in the wire coil, supports it in position, with a gentle pressure between the carbon points.

The connection with the electric source being made, the solenoid magnetises B, which is attracted into the coil. The action is as follows:—The

current passes into the coil, up through the carbons, and at once separates them. If the separation has been too sudden or far, the weight will bring the points nearer to each other again. The arc is established as soon as the current passes, and the weight should so counterbalance the column that its action may not be too strong for

the current. It will be found best to have the counterpoise adjustable.

Fig. 82 represents a coil and bobbin of wire for this lamp, having within it the iron column, with the carbon rod fixed in the top. For a lamp to burn, say, for $1\frac{1}{2}$ hours, with a light of 500 candles, the wire may be No. 12, and it should be silk-covered.



Fig. 82.—Bobbin for Archereau's Lamp.

The bobbin should be of hard wood, with a thin tube. It may be 5 inches long, and the central chamber may be $\frac{3}{4}$ in. in diameter, while the diameter of the sliding column may be $\frac{1}{2}$ in. or even less. The total length of the column may

be 7 inches, and it should be provided with a brass or iron socket, having a $\frac{3}{8}$ -in. hole in its

end for the reception of carbons of different sizes.

The total height of the lamp may be 13 inches, and the cord pulley must be placed above the middle portion of the main pillar, as represented, in a slot cast or cut for it. It will be found convenient to have the right-angle arm adjustable around the main pillar as an axis by a thumb-screw; and it is useful to have the top carbon screw or socket drilled right through, so that the carbons may be pushed downwards from the upper side.

The base must be solid and firm. It will be found best in most cases to provide one of cast-iron, and to insulate the binding-screw from it by fastening a block of wood in a $\frac{1}{4}$ -in. hole cast in the base.

Of carbons, the size will depend altogether upon the strength of current to be used in the production of the light. This lamp is very well suited to the current as obtained from voltaic batteries, and it will prove useful to give sizes of carbons best suited to different strengths of such currents.

A current from 50 cells of the Bunsen, or 40 of the bichromate of potash cells, will consume from $\frac{1}{4}$ to $\frac{5}{16}$ -in. carbon rods, and if the cells are large the carbons may be ordinary $\frac{3}{8}$ rods; for smaller numbers of cells the $\frac{1}{4}$ -in. rods will be found quite large enough. Round rods are better in work than square rods. They should be pointed on commencing the light.

Gaiffe's Lamp.

This lamp bears a strong resemblance in principle to the regulator devised by Archereau, described above.

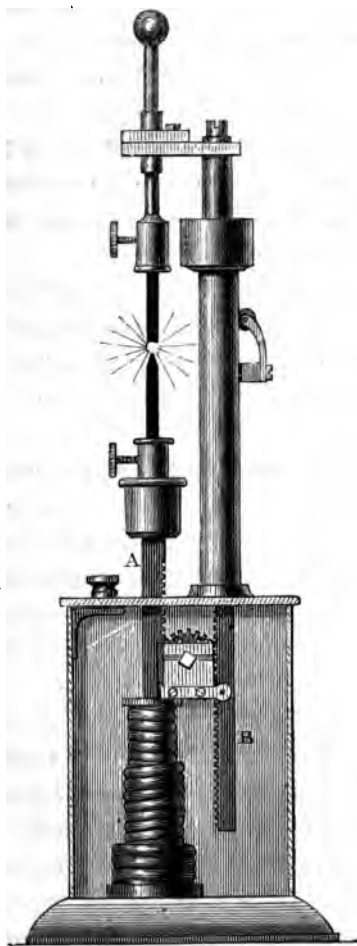


Fig. 83.—Gaiffe's Lamp.

It has a vertical coil of thick wire (Fig. 83), into which the lower carbon bar, A, is drawn when the current passes. This bar, unlike that used in Archereau's lamp, is toothed throughout a portion of its length, and actuates a wheel of 25 teeth, the axis of which carries another wheel of 50 teeth, insulated from the axis. The second, or largest, wheel engages another racked bar, B, actuating the upper carbon, and any motion of the first bar

in its coil gives a rate of approximation of 2 : 1 to the bars, the upper having, of course, to move the faster to make up for the greater length burnt.

Fig. 84 shows the racks, E and E; F is a pair of wheels bearing the ratio 2 : 1 to each other's effect upon the racks.

In order to maintain the contact between the carbons when the current is not passing, a clock-spring is provided upon the axis of the wheels, and this constantly urges the carbons together. The strength of this spring is such, that the pull of the bobbin upon the lower bar, when the current passes, will overcome it, and separate the carbons to the required distance for the production of a brilliant light.

All the parts of each carbon holder are, of course, insulated from each other. There is a great advantage in this arrangement, as applied to such purposes as require the light to occupy one point continually, such as in lighthouse illumination and the working of various instruments, including optical-lanterns, &c. It is a well-constructed and arranged lamp, and on account of its simplicity its working may be understood at a glance. The Gaiffe lamp is not, however, adapted for the consumption of very large and long carbons. Otherwise it may be said to possess all the advantages claimed for the Serrin lamp. It is fixed upon



Fig. 84.
Lamp Rack-
work.

a steady base, and a circular metallic case encloses the working parts.

Duboscq's Lamp.

The regulator connected with the name of Duboscq was invented originally by Foucault, though the mechanism has been considerably improved by Duboscq. This lamp is well known in England, as it was for a long time the only efficient regulator of vertical carbons obtainable. It has had considerable application in the production of elec-

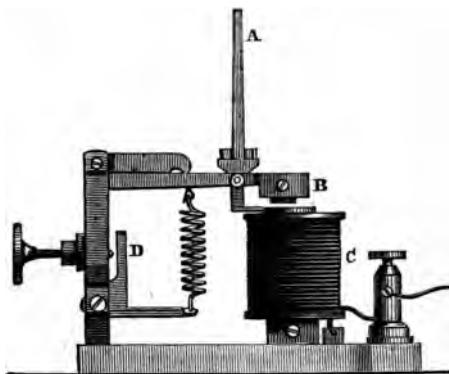


Fig. 85.—Detent of Duboscq's Lamp.

tric light for demonstrating purposes, such as the experiments of lecturers and occasional displays.

It has the same kind of regulating arrangement as Gaiffe's lamp. The racks are, however, in this arrangement actuated entirely by a clockwork spring and train, and the current only performs the part of stopping and releasing this train when

the carbons are apt to go too near to each other, or the current becomes too weak by too great separation of the points.

Fig. 85 exhibits the arrangement adopted for stopping and releasing the train as required. A is a metallic finger or detent, which stops or releases the mechanism contained in a case above. B is a soft-iron armature to which the detent is attached; C is an electro-magnet, by which the current is enabled to control the movement of the parts as required. D is an arrangement controlling the spiral spring shown, which balances the attractive force of the magnet when in work.

The current may be said to have almost perfect control over the movements of the points, and permits approximation to each other until the arc or separation for light is of a suitable length for the current to maintain. The arrangement D, acting upon the antagonistic spring, enables the adjustment of the lamp to any given strength of current to be easily made by hand before closing the circuit. In this lamp also the points are kept as nearly as possible in one position, and for this reason the arrangement is suitable for lighthouse work.

Siemens' Lamp.

This lamp was originally devised by Herr Häfner von Alteneck, who was the inventor of the particular mode of winding the wire on the armature

in the Siemens' dynamo-electric machine in its present form.

As in several other lamps, Siemens' apparatus has the carbon holders racked. The pinions of the racks are on one axis, and of such diameters that the upper carbon has double the run of the lower.

Fig. 86 exhibits the chief peculiarity of this lamp.

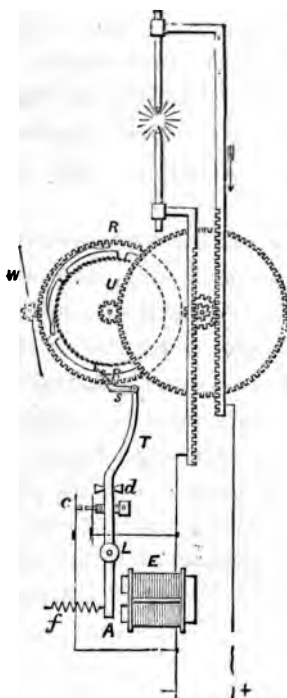


Fig. 86.—Siemens' Lamp.

It will be observed that it consists of an electro-magnet arrangement, A, L, T, through which motion may be communicated to the ratchet wheel, U, by the pawl S. L is the fulcrum of the magnet armature, which is caused to oscillate opposite to the poles of the electro-magnet, E, by reason of a contact-breaking arrangement being situated at C, with an adjustable platinum-tipped screw. The armature is pulled from the magnet poles by an antagonistic spring, *f*. When the spring is enabled, by the cessation of magnetism in the magnet, to pull to itself the armature, the pawl, S, is compelled by a pin to

leave the teeth of the ratchet wheel, U, and the upper rack may then descend, causing, as it does

so, the under rack to ascend at half the speed. The current passes, as indicated by the arrow, up one wire and rack and down the other.

This lamp is suited to work either with alternating or direct currents, but if alternating currents are used, there is no need for the contact-breaking stop, C, the change of polarity in the connections giving the required motion.

In the case of a direct current, the action is as follows:—As soon as the current passes, a small light is shown at the point of contact of the carbons, and this passage of current causes the electro-magnet to work the armature with an oscillating motion until the pawl has separated the carbons through the rotation of wheel U. When the separation is sufficient the current is weakened, and the antagonistic spring prevents the weakened magnet from giving further motion to the wheel. A continuous check is thus kept upon the falling tendency of the rack with the upper carbon. This lamp is admirably suited for lighthouse and general purposes.

The Siemens and Häfner-Alteneck Pendulum and Differential Lamps.

This lamp, the invention of Herr Häfner von Alteneck, recommends itself at once by the almost total absence of wheels and the simplicity of its moving parts. The lower carbon-holder is in this lamp a fixture, and the upper carbon-holder is formed by a rack, which in sinking down turns

a pinion. In order to moderate the speed with which this pinion turns, a common escapement-wheel with its pendulum is fixed to the same axle. A movable frame, serving as a guide to the upper carbon-holder, carries the pinion, and the pendulum, being lifted, more or less, by a solenoid acting on an iron core connected to the framing. During the normal burning of the lamp, a small lever fixed to the movable frame catches the pendulum, preventing it from moving, and thus keeping the upper carbon-holder stationary. When the arc becomes too large, or the current is weakened by other causes, the solenoid will let the frame drop a certain distance; the free end of the little lever is arrested by a projection of the lamp-casing, and the pendulum is free to move. The upper carbon will then at once descend, but as soon as the distance between the carbons is diminished, the strength of current will increase, lift the frame, and the little lever will again stop the downward motion of the upper carbon-holder. In order to lessen the suddenness of the motion of the framing, an air-pump is connected with it, and a spiral spring is attached to the core, by which the attractive force of the solenoid can be more or less assisted according to the strength of the current. In practical work this form of lamp has proved to be very efficient, as its management is easily understood. Similar lamps have been used in the British Museum, where all the apparatus has been managed, after the first fortnight, by the Museum authorities themselves,

and no difficulty has been experienced by them in maintaining the regulators in good working order. Lately these lamps were exchanged for others which work on the same principle, but have the case containing the solenoid and the moving frame above the point of light. This modification has been adopted because it facilitates the construction of suitable lanterns, but it does not differ from the form first described in the way of regulating the approach of the carbons.

In the lamps just described, as in most of those of other makers, the strength of current regulates the distance of the carbons, and the consequence is, that it is not in every case practicable to connect two or more of them in one circuit. To overcome this difficulty, Mr. Von Alteneck used another principle, which in some respects resembles the pendulum lamp. The upper carbon is attached to a similar rack moving in a slide, and turning a pinion with pendulum attached, but the motion of the movable frame is governed by *two* solenoids instead of one. The frame is attached to a lever, which carries a double iron core reaching into the two solenoids. One of these acts in the same way as the solenoid of the pendulum lamp, separating the carbons whenever a current passes through it. The other one consists of fine wire having a high resistance, and forms a shunt to the main circuit, the ends of the fine wire being connected direct to the terminals of the lamp, and by attracting its core it brings the carbons together

or releases the pendulum respectively. The action of these solenoids will, therefore, be balanced when the difference of potential on the two sides of the arc is of a certain magnitude, depending on the relative position of the two coils and the resistance of the wire on them. By this arrangement the quantity of the current flowing through the lamp has no influence on the relative position of the carbons, and nothing prevents a large number of them being inserted into one circuit. In producing light by alternate currents as many as 24 of these lamps have been worked in series, and their behaviour was all that could be desired. In order to make these lamps independent of each other a little contact piece is attached to the movable frame, which makes a short circuit from one terminal to the other whenever the frame is in its lowest position.

The principle of the action in this differential lamp is exhibited by Fig. 87, where g and h indicate the carbons held respectively in the sockets a and b , and provided with means of feeding as they are consumed. One socket, a , is attached to one arm, c' , of a lever pivoted at d , and having its opposite arm, c , connected to a piece of non-magnetic material uniting a pair of iron cores, s s' . The core, s , is free to play up and down within a solenoid R , the coil of which is of large wire offering small resistance, and forms part of the lamp circuit. The core s' is free to play up and down within a solenoid T , having a coil of smaller wire offering a greater resistance than

the coil of R. The coil of T is in a circuit external to the lamp, that is to say, joining the conductors L L', excluding the carbons. When the solenoid R, being excited, draws in its core *s*, the points of the carbons are separated; when on the other hand the solenoid T draws in its core *s'*, the carbons are caused to approach each other. As the relative force of the two solenoids depends upon the strengths of the currents of electricity passing respectively through the coils, and as this depends upon the relative resistance of their respective circuits, the one circuit, consisting of the coil T and its connections to the main circuit of L L', and the other

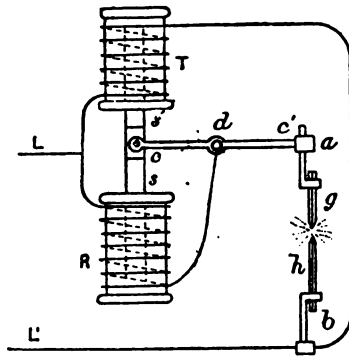


Fig. 87.—Siemens' Differential Lamp.

consisting of the coil R, the two carbons and the arc between them, that portion of the latter which consists of the arc being dependent on the distance of the carbons apart, this distance will become adjusted automatically by the action of the two solenoids, so as practically to maintain constant the action of the lamp. If, for example, the carbons should be too near together, a larger proportion of the electric current passing through coil R than through coil T will cause the superior attraction of

the core s , separating the carbons, and thereby increasing the resistance of the arc between them, and so lessening the quantity of electric current that passes through them. If, on the other hand, the carbons should be too far apart, then the coil R , being less excited than the coil T , will exert less attractive force on its core s , permitting the other core s' to be drawn into its coil, and thus causing an approach of the carbons which will lessen the resistance of the arc between them, and so permit the passage of a larger proportion of the current through them; thus the regulation of the lamp being dependent only on the resistance of its voltaic arc, and independent of the strength of current, the action of any one lamp in a circuit will not affect that of other lamps in the same circuit, and consequently a number of such lamps can, by means of this invention, be effectually worked in one and the same circuit.

Both in the "pendulum" and in the "differential" lamp the lower carbon is fixed, the focus of the light will therefore gradually descend. For some purposes it is, however, necessary to keep the focus in the same place, and Dr. William Siemens has suggested a simple contrivance to attain this end. The lower carbon is enclosed in a tube and, by means of a fine wire, a roller and a weight, is pushed against a screw fixed to the upper end of the tube. As the carbon wastes away by the action of the current, fresh carbon is fed upwards by the weight, and the shape which the carbon assumes

admits of the screw being far enough away from the arc to prevent its being injuriously affected by the heat. It is obvious that in such a case much longer carbons can be used, and that the time during which a lamp can remain alight without removal of carbons, is thereby very materially increased.

This "abutment" pole is employed for both electrodes in the last form of lamp invented by Dr. William Siemens, but the screw, against which the carbons are pressed, has been replaced by a knife-edge, which appears to give better results. In this lamp the carbons are placed horizontally, and their tubes are attached to Bell crank-levers, the other ends of which support the core of a solenoid, on which fine wire is wound, forming a high resistance shunt from one terminal to the other. The action of the lamp is very simple; the weight of the core, which can be varied at will, keeps the carbons apart when no current passes. As soon as a current arrives the solenoid will lift the core, the carbons touch for a moment and the arc is established, the further regulation depending again on the difference of potential *only*, and being independent of the *strength* of the current. No wheels whatever enter into the construction of this lamp, and all its parts are exceedingly simple.

Lontin's Lamp.

M. Lontin, inventor of the Lontin dynamo-electric machine, has sought to improve upon the

well-known Serrin lamp by introducing parts for its working of greater simplicity than hitherto.

It would appear that this inventor bases one part of his improvement upon the Serrin lamp upon the expansion of a metallic bar by the passage of the current through it, and by substituting this bar for the electro-magnet employed in Serrin's lamp.

M. Lontin has also invented a form of lamp in which any length of carbon rods may be employed. The lamp and carbons in this invention are horizontally placed, instead of vertically, as in most other lamps. The carbon holders are hollow throughout, so that any required length of rod may be inserted in them.

One of the carbons, as it passes through its support, is moved by a pair of rollers bearing with gentle pressure against it. This rotation is kept up by bevel wheels actuated by a spring and clock movement in the case of the lamp.

There is a disadvantage, however, in placing the carbons horizontally, as they are found to give much less light than vertical ones.

This lamp is not quite new. An invention brought out several years ago employed the tubular holders and the driving by clockwork; and the mechanism was, perhaps, as effective in use as that here spoken of, while the position selected was a vertical one, which is certainly superior to the horizontal plan, when the light power from a given current is considered.

Carré's Lamp.

The inventor of the Carré induction (high tension) machine has produced a lamp which is judged by some to be an improvement on Serrin's lamp. He employs a double solenoid instead of an electromagnet, which is supplied with an armature of S shape. This armature is caused to oscillate round a spindle, or pivot axis, at its centre, and the two ends enter a curved bobbin. When, from any cause, the current is interrupted, this armature is withdrawn by springs as usual, a detent releases the mechanism, and the carbon points come into close contact, so re-establishing the current. As in Serrin's lamp, the mechanism of Carré's device is actuated by the falling weight of the upper carbon holder.

When the current passes, the ends of the armature are sucked into the solenoid, and the carbon points are at once separated to the distance required to produce the voltaic arc.

Brush's Lamp.

The arrangement of the controlling device in this lamp admits of a large number of arcs being maintained in one circuit. The lamp consists essentially of three parts, namely, an arc-regulating device in two parts, and an automatic "cut-out," which throws the lamp out of the circuit if it becomes faulty.

The arc-controlling arrangement consists essentially, in the first place, of an electro-magnetic solenoid A (Fig. 88), forming a hollow cylinder. It is wound with two helices of wire, consisting, the first, of one or two layers of thick wire, and, secondly, of several layers of fine wire in reverse directions. The thick wire coil is in circuit with the arc, and offers no appreciable resistance, and the most of the current passes through it. The thin wire coil is really a shunt to both the thick wire coil *and the arc*, and offers a resistance of about 200 ohms; thus as long as the current passes through the carbons a small portion of the current passes through it and around the cylinder in the *opposite* direction to the course of the main current. The electro-magnetic effect of the thick wire solenoid is therefore partially neutralised by that of the thin wire solenoid; for although only a hundredth of the main current flows through the fine wire coil, its influence upon the attractive power of the cylinder is very considerable, owing to the greater number of convolutions it takes around the core. The real part played by this device is described further on. Meantime, it is necessary to describe the nature of the device by means of which the motion of the carbon is controlled. In this lamp the lower carbon is fixed; the upper carbon rod is therefore that under the control of the current.

B is a hollow iron core, fitting easily into the aperture in A. This core is free to move up and down a short distance. Within the core, B, is a

brass rod, C, which also constitutes the upper carbon-holder. This rod is loose in the aperture of B. At D is shown a lifting finger attached to B; its extremity is curved and passes underneath a brass washer or annular clutch, D, placed somewhat loosely on the rod C. This annular clutch is otherwise quite free.

E is a set screw, which is adjusted by hand. It is intended to control the movements of the clutch, D, by being screwed more or less down upon it.

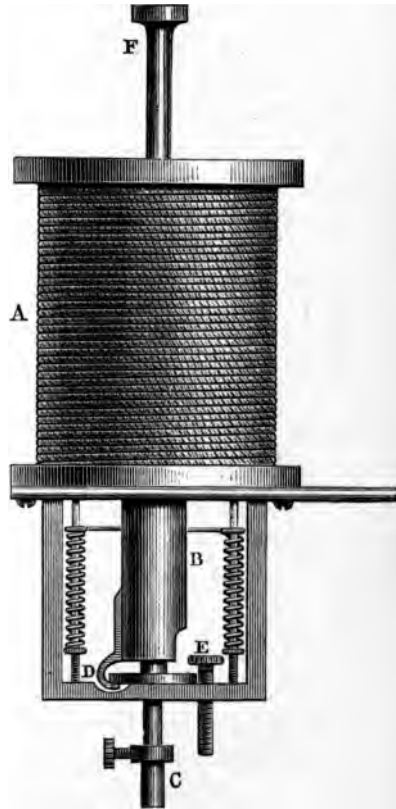


Fig. 88.—Part of Brush's Lamp.

If one wire from the dynamo-electric machine is connected to the lower carbon, while the other is connected to the commencing end of the wire coil, A, the other extremity of which communicates with the upper carbon-holder, the current will pass through the thick wire coil, the upper

carbon, the arc, and the lower carbon, so completing the circuit. The core cylinder, B, is then, by the force of the magnetism created, drawn up into the interior of A. By means of the lifting finger, D, it raises that edge of the clutch, until, by the latter's angular pressure upon it, the rod C is lifted upwards, and will be raised to such a height as may be determined by the height of the thumb-screw, E. As long, then, as the magnetism remains the same, the rod C, with its upper carbon, will remain fixed. While the current is not passing, the rod, C, is quite free to descend until its carbon point is supported by the lower carbon. This is the condition of the parts when the lamp is out of action, or when, by accident, the circuit is broken.

As soon, however, as the current passes, the core, B, is sucked into the cylindrical cavity of the bobbin, A, and in being raised also raises the washer by its finger, D, and with it the rod and upper carbon, C, until the voltaic arc is established between the carbons.

A pair of springs is represented in the figure, one on either side of the core, B. The function of those spirals is to support the weight of the core, B, with the aid of the induced magnetic attraction when the current passes. As the carbons are consumed the length of the voltaic arc increases, and with the increased resistance the current diminishes in strength. This weakens the magnetic pull of the wire coil, and the core, B, *with the rod, C, and upper carbon move down-*

wards by the action of gravity, until the consequent shortening of the voltaic arc so diminishes the resistance and increases the strength of the current that this downward movement is stopped by the increasing pull of the magnetic helix, A; or the clutch washer, D, will reach its floor or plate and its downward movement will be stopped, when any downward movement of the core, B, however slight, will at once release the rod, C, by allowing it to slide through the washer until the washer is again tilted by the upward movement of the core B, due to an increase of magnetism.

The carbon-holder rod, C, is hollow, and contains a mixture of glycerine and water, in which a small piston or valve is hung from a cast-iron hood, in order to prevent the upper carbon from falling too rapidly when released.

So far, the action of the solenoid is much the same as that in other lamps; but the distinguishing characteristic of Brush's lamp lies in the counter-controlling influence of the fine wire shunt, before mentioned. It will be clear that when the current flows it passes in opposite directions around the soft iron core, and that the latter will be attracted upwards if the current in the thick wire coil preponderates over that in the thin wire coil. If, under these conditions the arc should become too long, the current through the thick wire will be weakened, and that in the thin wire will be proportionately strengthened. The pull upon the core will therefore be weakened, and the upper carbon

will slide slowly downwards until the arc is shortened and the current through the thick wire strengthened. If the arc should become too short, the current in the thick wire will be increased and that in the thin wire diminished. The iron core will therefore be attracted upwards, and its annular clutch will raise the upper carbon until the length of the arc balances the attractive power of the solenoid.

It is this arrangement which allows of several of the arc lamps being included in one circuit. As many as forty arcs are so included in the working of the Brush system.

In the ordinary arc lamp we may conceive the secondary or shunt solenoid absent, and it will not be difficult to see that the regulating of its arc will depend entirely upon the strength of the main current. Hence, when more than one common lamp is so worked in one circuit, confusion at once ensues. In the Brush system, as in that of Siemens *differential lamp*, the arc is controlled not by the strength of the main current, but by the *difference* between the influence of the thick wire solenoid and that of the thin wire solenoid. The Brush lamp is therefore also a differential lamp.

But although the differential regulator serves to control the arc of the lamp while the circuit is complete, and although it effects this quite independently of the main current strength, a serious defect would still exist in the system if the lamps were liable to become extinguished, because the

interruption of the current in any one lamp would extinguish every other lamp in that circuit. The second distinguishing feature of the Brush lamp overcomes this difficulty in a most ingenious manner. An automatic "cut-out" is arranged, and so adjusted that if by the carbons being burnt out, or other accident, the current should be interrupted, the whole lamp may be thrown out of the circuit.

This is accomplished by means of another but smaller solenoid, similar to that already described. This solenoid is also wound with a short thick wire and a long thin wire. The long thin wire is in circuit with the thin wire of the arc-regulating solenoid. The thick wire, when in circuit, forms a shunt or by-pass to the whole lamp. Should the lamp become extinguished from any cause, as from the burning out of the carbons, the current in the fine wire of the arc-regulating solenoid would become abnormally strong. The same current would flow through the "cut-out" solenoid, and cause it to close the main circuit through its short thick wire, so throwing the arc-regulating solenoid out of the circuit. The current would then flow past the faulty lamp to the next. In the "cut-out" solenoid both currents flow in the same direction.

These arrangements are represented in the diagram, Fig. 89. A represents the arc-regulating solenoid, the main current from the junction-point x being divided into two branches, part of it flow-

close the thick wire shunt at the point G. This short-circuits the arc and the solenoid A, the result being that the proportion of the current now flowing in the fine wire is very small, and E would lose its power to attract F, did not the main current now flow in the thick wire round E. F, therefore, will maintain the contact at G so long as the current continues to flow in the circuit.

The ordinary length of the carbons employed in the Brush lamps is 12 inches. They are usually copper-coated to increase their conductivity, and vary in diameter from $\frac{7}{16}$ th inch to 1 inch, according to the power of the arc to be produced.

The ordinary lamp with a single pair of carbons burns eight hours. The Brush lamp with two pairs of carbons burns sixteen hours. In this lamp one arc-regulating solenoid controls both carbon rods. The annular clutches upon the rods are so adjusted that one raises its rod $\frac{1}{4}$ inch above the other, so that the second pair of carbons do not come into action until the first pair are burnt out and allow the second carbons to fall into contact.

The Thomson-Houston Lamp.

When an electrical current, which flows through a conductor of considerable length, is suddenly broken, a bright flash, called the extra spark, appears at the point of separation. This extra spark will appear although the current is not suffi-

cient to sustain an arc of an appreciable length at the point of separation.

In this system one or both of the electrodes, which may be ordinary carbon rods, are caused to vibrate to and from each other. The electrodes are placed at such a distance apart that in their motion towards each other they touch, and afterwards recede a distance apart which can be regulated. These motions or vibrations are made to follow one another at such a rate that the effect of the light produced is continuous, for, as is well known, when flashes of light follow one another at a rate greater than 25 to 30 per second, the effect produced is that of a continuous light. The vibrating motions may be communicated to the electrodes by any suitable device, such, for example, as mechanism operated by a coiled spring, a weight, compressed air, &c., but it is evident that the current itself furnishes the most direct method of obtaining such motion.

In a practicable lamp, instead of vibrating both electrodes, it is found necessary to give motion to but one, and since the negative electrode may be made of such size as to waste very slowly, motion is imparted to it in preference to the positive. The carbon electrodes may be replaced by those of various substances of sufficient conducting power. In this system, when desired, an independent current is employed to control the extinction and lighting of each lamp. The following is a description of one of the forms of electric lamp

which Messrs. Thomson and Houston have devised to be used in connection with their system of electric illumination.

Fig. 90 exhibits the construction. A flexible bar of metal, *b*, is firmly attached at one of its ends to a pillar, *p*, and bears at its free end an iron armature, *a*, placed over the adjustable pole-piece of the electro-magnet, *m*. A metal collar, *c*, supports the negative electrode, the positive electrode being supported by an arm, *j*, attached to the pillar, *p*. The pillar, *p*, is divided by insulation at *i* into two sections, the upper one of which conveys the current from the binding-screw marked + to the arm *j*, and the rod *R*, supporting the positive electrode.

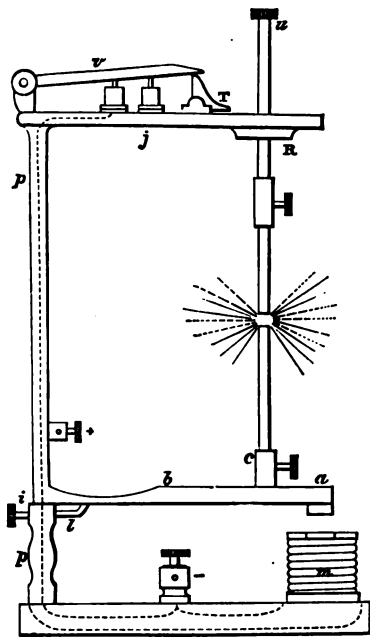


Fig. 90.—Thomson-Houston Lamp.

The magnet, *m*, is placed as shown by the dotted lines, in the circuit which produces the light. The pillar, *p*, is hollow, and has an insulated conducting wire enclosed, which connects the circuit-closer,

v, to the binding-screw marked —. The current is conveyed to the negative electrode through *b*, and the coils of the magnet, *m*. When the electrodes are in contact, the current circulating through *m* renders it magnetic, and attracts the armature, *a*, thus separating the electrodes; when, on the weakening of the current, the elasticity of the rod, *b*, again restores the contact.

During the movement of the negative electrode, since it is caused to occur many times in a second, the positive electrode, though partially free to fall, cannot follow the rapid motions of the negative electrode, and, therefore, does not rest in permanent contact with it. The slow fall of the positive electrode may be insured either by properly proportioning its weight, or by partly counterpoising it. The positive electrode thus becomes self-feeding. The rapidity of movement of the negative electrode may be controlled by means of the rigid bar, *l*, which acts, practically, to shorten or lengthen the part vibrating. In order to obtain an effective but free contact of the arm, *j*, with the positive electrode, the rod, *R*, made of iron or other suitable metal, passes through a cavity filled with mercury, placed in electrical contact with the arm, *j*. Since the mercury does not wet the metal rod, *R*, or the sides of the opening through which it passes, free movement of the rod is allowed without any escape of the mercury.

In order to prevent a break from occurring in the circuit when the electrodes are consumed, a

button, *u*, is attached to the upper extremity of the rod, *R*, at such a distance that when the carbons are consumed as much as is deemed desirable, it comes into contact with a tripping lever, *T*, which then allows two conducting plugs attached to the bar, *v*, to fall into their respective mercury cups, attached respectively to the positive and negative bind-posts by a direct wire. This action practically cuts the lamp out of circuit.

The Wallace-Farmer Lamp.

Fig. 91 is an illustration of this lamp. A A are

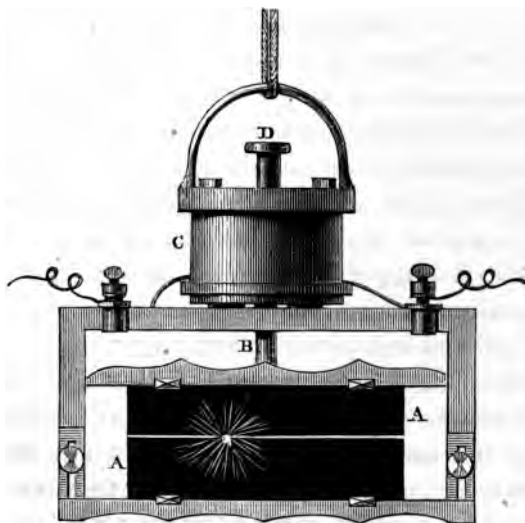


Fig. 91.—The Wallace-Farmer Lamp.

two *plates* of carefully prepared carbon, and the object of this invention is to so cause the light to

burn between them, that the automatic adjustment so often necessary in other lamps is here only necessary about every half-hour. The plates in the latest form of this lamp are about 9 in. long, 5 wide, and the upper is double the thickness of the under—this thickness in turn depending upon the strength of the current to be employed. The lower plate is fixed to the frame, but the upper plate is under the control of an electro-magnet through the rod B. This provides for the contact between or separation of the plates, as the current may require, to produce the maximum amount of light. The electro-magnetic arrangement, C, consists of an ordinary electro-magnet, having its poles downwards, and the rod D B has attached to it a soft-iron armature. When no current passes, the electro-magnet has no effect, and one carbon rests upon another; but when the current is passed, the arc of light forms where there is least resistance, and the electro-magnet at the same instant pulls up the upper carbon and makes the required separation. The distance between the plates may be regulated to a nicety to suit any current.

The light, as before stated, starts at the point of least resistance, and it burns its way horizontally along the carbon edges and back again until the arc is too long, when it is necessary to screw down the rod D a turn or two. In this way the lamp may burn for many hours at a time. As many as 10 of these lamps have been maintained in circuit of a Wallace-Farmer machine. It was tried in

England, and gave considerable satisfaction. It is, however, unsuited to purposes requiring the light to be kept in one point.

Rapieff's Lamp.

The leading peculiarity of M. Rapieff's lamp consists in the use of duplex carbons. Most other lamps employ only one solid carbon rod for each burning point; but Rapieff uses two—that is, four altogether. These rods are inclined to each other to form one upright and one inverted V, and at the point of intersection the electric arc is produced as in other lamps. The rods used by this inventor are necessarily of half the sectional area they would have if not double.

Fig. 92 will give some definite idea of these arrangements, where the four rods are represented in the interior of a glass globe nearly in contact. The upper pair of rods are always the longer, because they burn away the faster. The duplicate arrangement of the rods presents the advantage that one of them may be removed and renewed without extinguishing the light. This is the chief advantage of the whole arrangement. M. Rapieff



Fig. 92.—Rapieff's Lamp.

also recognises the advantage of making the electrical contact with the rods as near to their points as possible. This has the effect of greatly decreasing the resistance of the lamp.

The upper carbons are free to slide in their holders, and as their points come into actual contact, they are stopped from further motion. As far as this end of the circuit is concerned it is self-feeding, for as fast as the points burn away the length is renewed by their weight pressing them downwards.

When the current is interrupted, the two pairs of points come together by movement on the part of the lower pair only. As long as the current does not pass, a light spring supports the lower pair, and gently presses them against the upper pair. Fastened to the free end of both upper carbons is a silk thread, which passes over a pulley, and is attached to a sliding-weight in the supporting-pillar of the lamp. When the current passes, the lower pair of carbons is caused through its spring to be separated the required distance to produce the voltaic arc. There is communication between the vertical rod actuating the lower carbons and an electro-magnetic arrangement concealed in the base of the lamp.

This consists simply of two electro-magnets, one of which is fixed to the base, while the other is pivoted or hinged, and by its approach to the fixed one moves the vertical rod controlling the lower carbons, and these are thus drawn away from the

upper pair. When the current ceases to flow, the spring before spoken of causes the hinged magnet to fall into its normal position, and the lower carbons at the same time touch the upper pair, to be in readiness to start the light when the current next passes.

Another good feature of the Rapiëff lamp is its arrangement (also concealed in the foot) for throwing a resistance of wire, equivalent to that of the lamp, into circuit when, through any cause, the circuit has been interrupted in the lamp. When the hinged magnet falls back, it instantly closes the circuit of this resistance of wire, and the machine is not affected, nor does it (the supposed accident) affect any other lamps in the same circuit, since the resistance remains constant, or very nearly so. There is also employed in these lamps a resistance consisting of a pencil of carbon, and through this, the resistance of which is equal to that of the lamp, the current passes when the lamp breaks circuit.

By means of these carefully thought out arrangements, as many as 6 and 8 lamps of this type have been kept alight upon one circuit only, and any accident to one lamp did not affect the others; or any lamp might be extinguished and relighted without any effect being apparent upon the main circuit.

This system has been in practical use in the composing-room of the *Times* newspaper, and gas is thus entirely replaced by electric light.

The construction of the lamp is not so well carried out as the plan, and the parts are unnecessarily delicate, which should not be the case in a practicable lamp for general use. M. Rapiéff has also brought into use a lamp in which both pairs of carbons pass up from underneath, forming an inverted V. The arc impinges upon a piece of lime, which increases the light. M. Rapiéff has also invented an electric "candle."

Crompton's Lamp.

In this lamp the inventor has aimed at reducing the weight of those parts that require movement for the more delicate and final adjustment of the distance between the carbons. In its latest form the mechanism is above the light. The negative carbon is below the positive, and attached by an arm to a rod fast to the armature of the magnet. A spring keeps the armature and rod up, when the magnet is not acting. The positive carbon is fast to a rod which by its weight constantly tends to descend towards the negative carbon, and in doing so, by means of a rack, causes a train of wheels to work.

On the top of the armature of the magnet is hinged a smaller piece of iron, or jockey armature, carrying a brake which can act on the train of wheels. A small light spring keeps the brake from touching the wheels until a current sufficiently strong causes not only the armature to be drawn down and come in contact with the magnet, but

also causes the smaller jockey piece on the top of it to be drawn down and apply the brake. The action is as follows: 1. When no current is circulating, the positive descends and touches the negative. 2. On a current being established, the electro-magnet draws down the armature, thus lowering the negative away from the positive and establishing the arc. 3. The positive then begins to fall until the current becomes sufficiently strong to attract the small jockey armature, causing the brake to be applied and stopping the descent of the positive. The lamp is very sensitive, as, instead of having several pounds to be thrown in and out of motion for each adjustment, the portion to be moved by the change of current is only a few grains. The adjustment consequently takes place every few seconds.

Urquhart's Lamp.

Figs. 93 and 94 are views of this lamp. The same letters refer to the same parts in both figures. Fig. 93 is an end elevation of the lamp, and Fig. 94 a side elevation.

A A are a pair of carbon plates, carefully made from the best materials used in the composition of rod carbons. These plates are of any suitable length, and 6 inches broad. Their length may be 12 inches. These plates are of different thicknesses, the positive one being the thicker because it burns away the faster. They are made to slide freely through the hollow cores of a pair

of flat electro-magnets, B B, which are connected

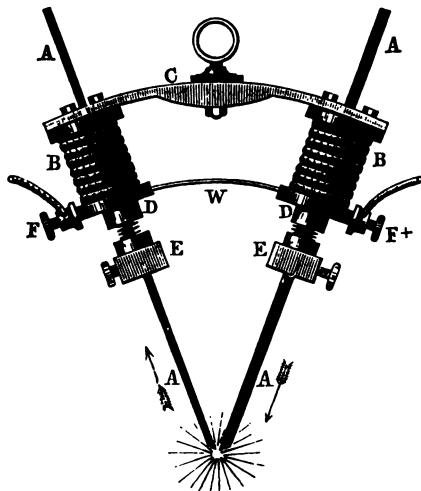


Fig. 93.—Urquhart's Lamp: End.

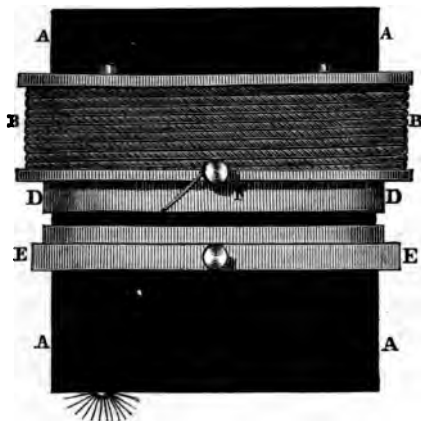


Fig. 94.—Urquhart's Lamp: Side.

by a strong bridge of hard wood, C, provided with

a ring for suspending the lamp. The carbon plates pass downwards until they meet at the point where the light is shown, thus forming a V. The plates pass also through two hollow armatures, E E, provided with set-screws by which the plates and armatures may be made fast together. The armatures are kept away from the magnet-cores by a pair of long brass springs. Fig. 94 will show more clearly how each plate is made to pass through the electro-magnet system.

When it is required to put carbons in the lamp, plates of suitable size, and about $\frac{3}{8}$ -in. in thickness for common currents, are selected, passed through the magnets until they touch at their lower edges, and there fastened by the screws, E E. Thus the carbon plates and the armatures act as one, and are free to move upwards to the poles and down to the point where the plates meet. The current enters at F +, passes through the coil of thick wire, B, and then to the core of the magnet—including the armature, which is metallically connected by a spring, and passes down the positive plate, up the negative plate (as shown by the arrows), through the coil of the left-hand magnet, and so completing the circuit at F.

The current has thus a circuit of little resistance. When it passes, it instantly makes B and B magnetic, which attract the armatures, E E; and, the plates rising with them, the voltaic arc is established, and of such length as may suit the current passing.

The arc forms at the point of least resistance between the near edges of the plates, as in the Wallace-Farmer lamp, and from this point it creeps along the edges of the plates to the farthest extremity. The time occupied in doing this will depend upon the strength of current at work. When the arc has burned its way from end to end of the plates, the voltaic arc becomes too long, the current weakens, the magnets release their hold slightly, and the arc is re-established. Thus the action of the lamp is quite motionless for periods of at least half an hour each, and only controls the length of the arc by keeping a constant up-pull upon the plates. It is only about every half-hour that the plates move at all, and when they do move downwards to make up for burnt carbon, the distance is very small, or only half that burned off the plate edges.

The magnets are coiled with one layer of No. 10 wire only, and the size of the carbon plates permits of a very low resistance in that direction. There is, further, the advantage that the resistance of this lamp is almost constant, and does not vary, like that of Serrin's regulator, from perhaps 5 ohms to 8 ohms in a few hours.

w, in the first figure, represents the edge of a reflector of polished metal or other suitable material; it serves to throw any light diffused upwards in a condensed beam through the carbon separation; and, to insure that no light is lost, this reflected portion may be thrown downwards quite

clear of the arc itself, by making one end of the reflector slightly higher than the other.

It will be noted that remarks are made in preceding pages concerning the fact that a horizontal arc does not give so much light as a vertical one. It may be thought that the lamp now under consideration will give a horizontal arc; but this is not the case, because one carbon is always, from causes affecting the attraction, above the other, and the arc forms in a diagonal line.

Weston's Lamp.

The action of this lamp is similar to that of the Brush. Instead of a solenoid Mr. Weston employs a pair-limbed electro-magnet, which is coiled with two wires. One of the helices is of thick wire, and carries the greater part of the current; the other is of finer wire in a larger number of convolutions, and conveys a percentage of the current; it thus forms a shunt to the arc.

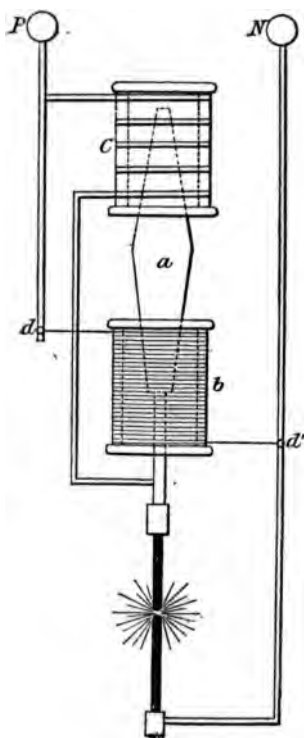
The Pilsen Lamp.

The special feature of this lamp lies in the use of a bi-conical or spindle-shaped iron core. When such a core is suspended between and partially through the interiors of two electro-magnetic solenoids, placed one above the other, and an electric current is passed through the solenoids, such a core has no positive or balanced point (as is the case when a plain cylindrical core is used), and it thus

has a lengthened extent of movement vertically in the solenoids. This principle is utilized directly in the regulation of the arc and in feeding the upper carbon downwards.

The lamp consists essentially of a soft iron core of the shape described, *a* (Fig. 95), and of two solenoids, *b* and *c*. *b* is

wound with fine wire, and forms a shunt or by-pass to the arc from the point *d* to the point *d'*. *c* is wound with thick wire, and is in direct circuit with the arc.



The resistances and electro-magnetic influence of these two coils are so balanced that, although about 1 per cent. only of the current flows around *b*, they have equal effect upon the core when the length of the arc is properly regulated (from 1 to 2 millimètres).

Any alteration in the resistance of the arc, by its becoming too long or short, disturbs this balance, and one or the other of the solenoids begins to act, by attracting the core downwards or upwards.

Fig. 95.—Diagram of the Pilsen Lamp.

If the arc becomes too long, by the burning away of the upper carbon, the current in *c* will become weak, and that in *b* proportionately stronger. Hence, the electro-magnetic attraction of *b* will preponderate on that of *c*, and the upper carbon will descend until, the resistance of the arc being reduced, the current in *c* will balance the effect of that in *b*. Should the arc become too short, the proportion of the current flowing through *b* will be diminished and that through *c* augmented; therefore *b* will release and *c* will attract the soft iron core, raising the upper carbon to the required distance. The influence of the solenoids upon the core is assumed to be the same for all positions of the core within them.

Rotating Disc Lamps.

Many attempts have been made since 1846 to produce a good lamp having rotating discs of carbon instead of the usual rods. Wright was the first to employ this idea, and it has been taken up by several others, with modifications and improvements from time to time.

The discs revolve regularly upon two metal axles, put in connection with the poles of the battery or other generator of electricity, and present successively, by the combined rotation and approximation provided, all the extreme points of their circumferences to the production and emission of the electric light. At each revolution of

the discs, they are caused to approach each other by the distance they have burned inwards from the edge, to make the length of the arc constant.

Many different kinds of apparatus may be employed to cause the discs both to regularly rotate and also at each revolution to approach each other by the exact distance consumed. It has been done by means of clockwork and a spring or weight, and electro-magnetism is, of course, also available for the same purpose. Le Molt, whose lamp was produced and patented in 1849, produced the motion by the first method, and he employed cams upon a large brass disc to make up for the burnt portion of the carbon discs employed. This lamp would burn for over twenty hours at a time.

A great objection to this class of lamps lies in the fact that it is almost impossible to produce discs of sufficient purity to burn equal spaces in equal times, so that a regular motion is in practice of no use. The motion, however it is produced, must be under the direct control of the current itself, so that any augmentation of space burnt over may be compensated for by greater speed in the discs, and a decrease of carbon space burnt by less speed. Arranged vertically, one disc edge above the other, and thus controlled, there is no reason why this should not make a good continuous lamp.

Lamps in which the Carbons touch.

In the lamps previously mentioned, the carbons are, by clockwork, electro-magnets, or weights, kept automatically at a distance apart, so as to form the voltaic arc; in another class of lamps the carbons actually touch, and the light is emitted through the incandescence of the carbon at and near the points of contact, and also by arcs formed between points immediately around the points of contact, the resistance at the point of contact being sufficient to cause a portion of the current to form a belt of heated air forming the arc between the portions of the carbon situated near the point of contact.

Reynier's Lamp.

Reynier's improved lamp works with a rod and a disc of carbon. The rod is placed vertically, as usual in other lamps, and fixed to the upper arm. This upper arm of the lamp is movable, as in Serrin's lamp, and is also toothed. The support and the carbon rod thus move downwards together.

The racked bar, as it descends by its own weight, carrying its carbon rod, is made to impart motion to a pinion, which in turn rotates, through a larger wheel, the carbon disc employed. Thus the disc rotates in obedience to the descent of the upper carbon, and it will be evident that the carbon rod also acts as a brake upon the rotating disc to prevent too free a motion.

One peculiarity of the Reynier lamp is its employment of incandescence in the rod used. This carbon pencil is small although long, and the current is not made to traverse the whole of its length. The current is communicated to it a little way above its contact with the revolving carbon disc, and the part of the rod between where the contact is made with the conductor and its end is made white hot, and emits considerable light and heat.

It will be inferred that the unequal burning away of the disc, as it is softer or harder, must cause irregularities in the light, and this is in the foregoing construction really the case.

Some recent improvements effected by the inventor, however, make the light almost perfectly steady. The revolution of the turning disc is obtained from the tangential component of the pressure of the carbon pencil on the circumference of the disc. Thus the burning end of the pencil never leaves the moving contact, and it is said that all previous causes of irregularity are thus obviated. There is a brake retarding the progress of the rod, and it is operated thus :—The contact wheel is carried by a lever. The pressure exerted by the carbon on the wheel causes a shoe to press upon the face of a wheel, which is revolved by means of the weight of the holder rod through its rack and pinion. This lamp is suited for the weakest currents and displays of light, down to the current *from a few of Bunsen's cells.*

Werdermann's Lamp.

The principle embodied in the construction of this lamp is of much value. It is almost a true incandescent lamp, and in this respect may be compared to the Reynier apparatus.

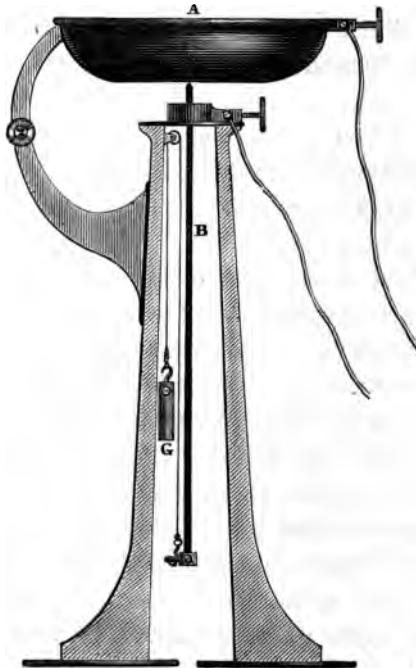


Fig. 96.—Werdermann's Lamp.

Fig. 96 represents one form of the Werdermann regulator. A is a rounded block of carbon, connected to the negative wire from the electric source. B is a rod of carbon, constantly urged upwards

against A by a weight, G, acting through a cord over a pulley as shown. It will thus be observed that the lamp is altogether of very simple construction, and has no clockwork or other regulating mechanism.

The inventor states that there is a repulsion between the carbon block and the point sufficient to cause a slight separation, so that the lamp is not simply an incandescent one, but possesses some of the peculiarities and advantages of open circuit lamps. When the current is passed, the carbon rod, at its upper extremity, becomes incandescent, and glows with a clear, steady light. For this purpose a thin rod is used.

The chief advantage claimed by the inventor lies in the fact that several of these lamps may be placed in one circuit, or, more correctly, in multiple arc connection with the electric source. This connection is made by taking two straight wires from the machine, but not joining their ends, and then placing the lamps so that they may connect the two wires together through them. The current is thus divided between the lamps, and the result is, or should be, an almost perfect subdivision of the currents. The number placed in one circuit is limited, however, for when too many are included, the subdivision does not hold good unless the main conductors increase in size with the number.

As many as from 9 to 12 lights of 50-candle power have been maintained with so small a current as that from a Gramme plating-machine.

When only 2 lamps were upon the circuit they gave, each, a light equal to 320 standard candles. This lamp has been repeatedly exhibited in London. In the later forms of Mr. Werdermann's lamp, a disc or cylinder of copper is substituted for the carbon disc. The principle of the lamp is in other respects the same.

The Brougham-André Lamp.

In this lamp a carbon rod, weighted, falls on to a cone of copper, the carbon being the positive electrode and the copper the negative. The carbon rod is inside a brass tube, and the copper cone is fast to an arm connected by a rod to another tube outside the one containing the carbon rod, and insulated from it. The outer brass tube is joined to a brass disc, to which is fastened the glass case enveloping the light, and this is kept air-tight by being immersed in a second glass case filled with water. Thus an air-tight joint is obtained and the light soon exhausts the oxygen, leaving gases which do not combine with carbon.

While the carbon burns away at the rate of six inches per hour in the open air, it is said to burn only one-eighth of an inch per hour when in the water-covered globe.

Joel's Lamp.

This is a semi-incandescent lamp, in which a pencil of carbon is caused to impinge upon a disc of copper. The light is partially due to the highly

incandescent condition of the extremity of the carbon pencil, and partially to a voltaic arc formed between the copper and the pencil. This arc is supposed to be due to a kind of repulsion between the carbon and the copper disc. The carbon pencil forms the positive pole from the electric source, and is consumed away. The copper being highly conductive, and forming, as it does, the negative pole, is scarcely, if at all, consumed in the arc. The pencil is fed up to the copper disc by means of the gentle pressure exercised by a weight and cord.

Electric Candles.

In all the arrangements previously described some means of moving the carbons, either by springs, gravity, or electricity, is employed, but if two rods of carbon are placed parallel, the arc, it is found, can be maintained between them, if the currents are used alternately in different directions, so as to consume the carbons equally. This idea first occurred to M. Jablochhoff, and is called an electric candle, as the carbons consume away from one end in the same way as the wick and wax of a candle. It was first thought necessary to have an insulating material between the rods, but this has been found unnecessary.

M. Jablochhoff's Candle.

In March, 1876, this "candle" was patented and introduced, and a remarkable movement to-

wards the application of electric light to public purposes was in consequence instituted. In Paris it took the form of lighting the Avenue de l'Opéra, the Place de l'Opéra, the Place du Théâtre Français, and numerous public buildings; and in consequence of the success attending these applications of the new light, it was tried successfully in workshops, railway depôts, and other places on the Continent and in America, while the same impetus carried the electric light to the Thames Embankment and other public places in London and the provinces.

The "candle" just mentioned consists of two rods of manufactured carbon, placed side by side, and insulated from each other by a strip of plaster of Paris, or kaolin, which was at first used for the purpose. Figs. 97 and 98 represent the rods and the complete candle. The rods used are about

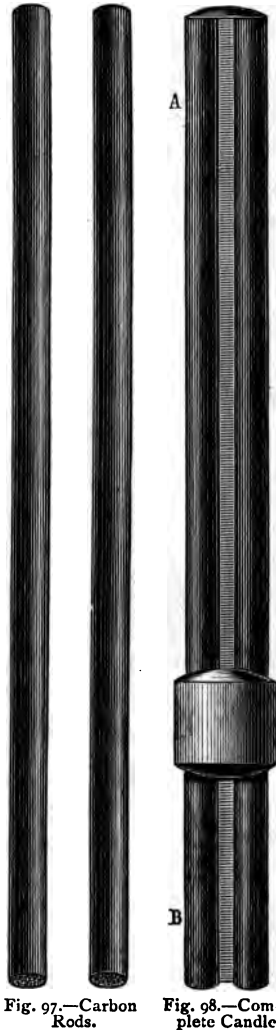


Fig. 97.—Carbon Rods.

Fig. 98.—Complete Candle.

$\frac{3}{16}$ ths of an inch in diameter, and from 5 to 15 inches in length. They are fastened in a pair of brass tubes, which are held together by an insulating cement, B. Across the top is a chip of carbon fastened in place by carbon powder and gum, and when the alternating currents pass this is fused and the true electric arc instituted.

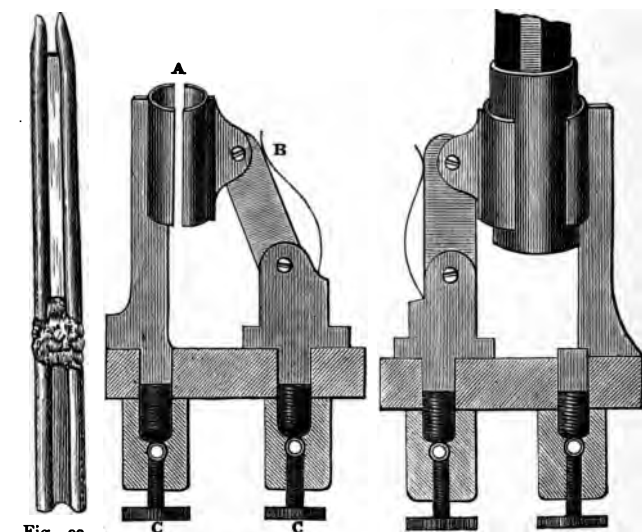


Fig. 99.—
From Photo
of half-burnt
Candle.

Figs. 100 and 101.—Jablochkoff's Candle-holders.

Fig. 99 is from a photograph of a candle partly burnt on the Thames Embankment, and shows the form assumed by the extremities of the carbon rods while in use. Both rods burn equally, on account of the alternating currents, which must always be employed with the candle with this

object. The plaster of Paris is fused as the candle burns down.

The candles most in use are ten inches long, and burn for about $1\frac{1}{2}$ hours. If this form of candle becomes extinguished, the arc cannot again be conveniently relighted—that is, it will not relight itself. Four candles are placed in one lamp, which has usually a cover of opalescent glass to tone down the intense glare. When one candle burns out, or before it burns out, another is switched into the circuit by an automatic arrangement.

Figs. 100 and 101 represent holders for the candles. They consist simply of two cheeks insulated from each other, one of them A, fixed, and the other articulated with a holding spring, B. The binding-screws, C C, convey the current to the holder.

One form of the automatic switch consists of a metallic finger, which is pressed against the candle by a spring, so that when the candle is consumed down to this point the finger will fall through it, and by a contact lever underneath switch another candle into circuit. Other more or less complicated arrangements are in use for the same purpose.

Wilde's Candle.

The maker and inventor of the well-known dynamo-electric machine (Mr. Henry Wilde, of Manchester) has also invented a candle and holder

similar in some respects to that of M. Jablochkoff. From his experiments in connection with the Jablochkoff system, Mr. Wilde deduces several very important conclusions, bearing practically upon the question of electric burners of this type. One of the conditions necessary for producing a constant light from the candle, in its most recent form, was that the strength of the alternating current should be such that the carbons consume at a rate of from 4 to 5 inches per hour. If the electric current is too powerful, the carbons become unduly heated, and present additional resistance to the passage of the current. The points at the same time lose their regular conical form. If, on the other hand, the current be too weak, the electric arc plays about the points of the carbons in an irregular manner, and the light is easily extinguished by currents of air.

In the course of his experiments, Mr. Wilde was struck by the apparently insignificant part which the insulating material plays in the maintenance of the light between the carbon points; and it occurred to him to try the effect of covering each of the carbons with a thin coating of hydrate of lime, and mounting them parallel to each other in separate holders, without any insulating material between them. The use of the lime covering was intended to prevent the light from travelling down the contiguous sides of the carbons. On completing the electric circuit the light was maintained *between* the two points, and the carbons were

consumed in the same regular manner as when the separation was by means of plaster of Paris.

Two plain cylindrical rods of carbon, $\frac{3}{16}$ ths of an inch in diameter and 8 inches long, were now fixed on the holders, parallel to each other as before, and $\frac{1}{8}$ th of an inch apart. The strength of the alternating current was such that it would fuse an iron wire 0.025 in. in diameter and 8 feet in length. On establishing the electric current through the points of the carbons, by means of a conducting paste composed of carbon and gum, the light was produced, and the carbons burnt steadily downwards as in the first trials.

Four pairs of naked carbons mounted in this manner were next placed in series on the circuit of a four-light machine, and the light was produced from these carbons simultaneously, as when the insulating material was used between them. The light from the naked carbons was also more regular than that from the insulated ones, as the plaster of Paris insulation did not always consume at the same rate as the carbons, and thereby obstructed the passage of the current. This was evident from the rosy tinge of the light produced by the volatilisation of the calcium simultaneously with the diminution of the brilliancy of the light from the carbons. The only function, therefore, which the insulating material performs in the electric candle, as shown by these experiments, is that it conceals the singular and beautiful property

of the alternating current, to which attention has been directed.

This simple method of burning the carbons will greatly further the development of the electric light, as carbons can be used of much smaller diameter than has hitherto been possible. They may also be of any desired length, for as they are consumed they may be pushed up through the holders without interrupting the light. One of these developments will be a better method of lighting coal and other mines. In this application the alternating currents or waves from a powerful electro-magnet induction machine may be used for generating, simultaneously, alternating secondary currents or waves in a number of small induction coils, placed in various parts of the mine. The light may be produced in the secondary circuits from pairs of small carbons enclosed in a glass vessel, having a small aperture to permit the expansion of the heated air within. Diaphragms of wire gauze may be placed over the aperture to prevent the access of explosive gas. By generating secondary currents or waves, without interrupting the continuity of the primary circuit, the contact breaker is dispensed with, and the subdivisions of the light may be carried to a very great extent.

In the course of his experiments, it was observed by Mr. Wilde that when the electric circuit was completed at the bottom of a pair of carbons close to the holders, the arc immediately ascended to the

points, where it remained so long as the current was transmitted. His first impression of this peculiar action of the arc was, that it was due to the ascending current of hot air by which it was surrounded. This, however, was found not to be the cause, as the arc travelled towards the points in whatever position the carbons were placed, whether horizontally or vertically in an inverted position. Moreover, when a pair of carbons was held in the middle by the holders, the arc travelled upwards or downwards to the points, according as the circuit was established above or below the holders. The action was in fact recognised to be the same as that which determines the propagation of an electric current through two rectilinear and parallel conductors submerged in contact with the terrestrial bed, which was described by the same experimenter in the scientific papers of August, 1868.

In all the arrangements in general use for regulating the electric light, when the light is required the ends of the carbon pencils are brought into momentary contact, and are then separated a short distance to enable the light to form between them. The peculiar behaviour of the electric arc when the carbons are placed parallel to each other suggested to Mr. Wilde the means of lighting the carbons automatically, notwithstanding the fact that they could only be made to approach each other by a motion laterally, and to come into contact at their adjacent sides. To accomplish this object, one of

the carbon holders is articulated (jointed) or hinged to a small base-plate of cast iron, Fig. 102, C, which is so constructed as to become an electro-magnet when coiled with a few turns of insulated wire, E. The carbon holder, B, is made in the form of a

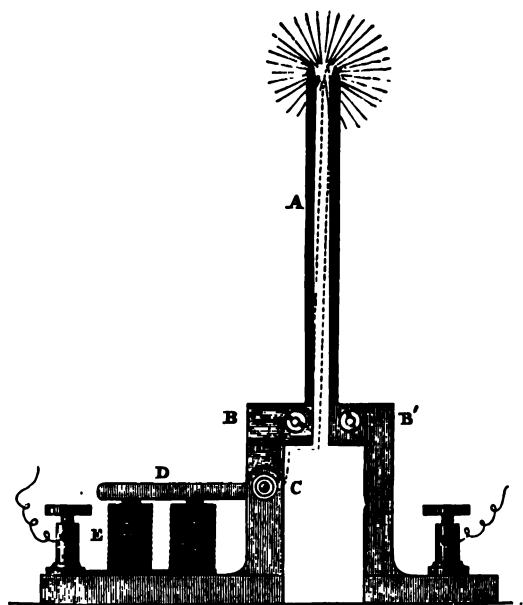


Fig. 102.—Wilde's Candle.

right-angled lever, to the short horizontal limb of which is fixed an armature, D, placed over the poles of the electro-magnet, E. When the movable and fixed carbon holders are brought into juxtaposition, and the carbons inserted in them, the upper parts *of the two carbons* are always in contact when no

current is transmitted through them, as shown by the dotted lines in the engraving.

The contact between the carbons is maintained by means of an antagonistic spring, inserted in a recess in one of the poles of the electro-magnet, and reacting on the under side of the armature. One extremity of the coil of the electro-magnet is in metallic connection with the base of the carbon-holder, while the other extremity of the coil is in connection with the terminal screw at the base of the instrument, from which it is, of course, insulated. The coils of the electro-magnet are thus placed in the same circuit as the carbon pencils.

When the alternating current from a dynamo-electric machine is transmitted to the carbons, the electro-magnet attracts the armature and separates the upper ends of the carbons, which brings them into their normal position, and the light is immediately produced. When the circuit is interrupted the armature is released, the upper ends of the carbons come into contact, and the light is produced as before. When several pairs of carbons are placed in the same circuit, they are by these arrangements lighted simultaneously.

Jamin's Blowpipe Lamp.

A curious application of Mr. Wilde's electric candle has been devised by M. Jamin, who, in a communication to the French Academy of Sciences, gives details from which the following

description has been deduced :—Wilde's candle, as just described, consists of a pair of thin carbon rods separated from each other, the arc forming between them. M. Jamin takes the negative electrode leading from the electrical generator, and, instead of fastening it in the binding-screw at once, makes it describe one or two turns around the candle, from top to bottom, as in Fig. 103, where A is the candle, and the nega-

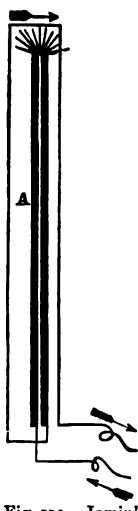


Fig. 103.—Jamin's Blowpipe Candle.

tive electrode is wound one turn round the candle longitudinally, as indicated by the arrows. It will be observed that the direction of the electric arc coincides with that of the outside current. The result of thus arranging the parts is that when the arc is formed it flares up like a gas-flame, being attracted by the passing current. M. Jamin then causes it to impinge upon a cylinder of chalk or lime, as in the lime, or Drummond light. He also employs magnesia. It has the effect of very greatly augmenting the amount of light, and of toning its quality from violet to yellowish green or white by the action of the lime. The heat is so intense as even to fuse the chalk, so that the inventor recommends its use to chemists and others as probably the most powerful flame known. It is, as yet, however, too expensive except upon a small scale. *It would appear to be necessary in practice to pro-*

vide some arrangement to move the lime body downwards to coincide with the receding carbon points.

A recent development of this beautiful experiment has appeared in the form of Jamin's candle-lamp. It consists of one or more candles, so arranged as to be each in turn automatically switched into the circuit. The whole is surrounded by several convolutions of insulated wire, so as to cause the diffusion of the voltaic arc in the manner demonstrated in M. Jamin's first experiment. Either the whole or a portion of the current may be caused to circulate in the convolutions of the attracting coil.

De Meritens' Candle.

A device by De Meritens would appear to extend the principle of the electric candle in another direction. This inventor employs a third rod of carbon between the other two, but not in contact with them. It is preferred to have it of half the diameter of the outside rods, and it occupies the place, and partly fulfils the function, of the insulating plaster of Paris or air.

The arc, once produced by any convenient means, plays between the outer rods and the central one, which it consumes. When the arc is thus divided between three rods it has less chance to be extinguished than in Jablochkoff's original candle, and the inventor considers that a smaller current

will in this case be necessary to produce an electric light of given power.

Rapieff and Siemens' Candles.

M. Rapieff and Dr. Siemens have produced candle-lamps. Their construction is different from that of Wilde, but the principle and the results are so exactly similar in both cases to that of Wilde that it will be unnecessary to go into details.

Incandescence in Vacuo and Gas.

When a powerful current of electricity is passed through conductors offering considerable resistance, the conductors become heated. If the current be continued, the conductors become white-hot and finally highly incandescent, emitting a light of considerable power. This property of the electric current is frequently shown by lecturers, who use for the purpose a chain composed of alternate links of silver and platinum. The silver being a good conductor, does not easily become heated by the current; but the platinum, having less conducting power, becomes white-hot.

When carbon in the form of graphite is subjected to the passage of a current, its resisting power is so high that it speedily becomes white-hot, and finally incandescent. In this condition it emits a clear white light, but speedily wastes away when exposed to the air. Platinum does not

waste so rapidly, but it has other disadvantages, and is more easily fused before the desired condition of luminous incandescence is attained. Many attempts have therefore been made to utilise carbon for the production of electric incandescent light, and enormous difficulties had to be overcome before carbon filaments could be utilised for this purpose.

After repeated trials and failures with incandescent carbon burned in air, it was thought that carbon in the form of thin pencils, enclosed in a glass globe exhausted of air, might, by being rendered highly incandescent by passage of the electric current, afford a permanent source of light, since it was believed that carbon would not burn and waste in vacuo. These attempts, although not few in number or undertaken by unskilled hands, failed in most cases with the early experimenters. So long ago as 1845 an American inventor, Mr. King, patented there and in England a lamp involving this principle. His light was produced in a vacuum, to prevent the oxidation of the incandescent carbon or metal, and was extremely promising for its beauty, brilliancy, and steadiness. But it failed to be permanent and economical from various defects and deficiencies, some of which have, of course, been removed by the increased power and economy of modern dynamo-electric machines, and by recent advances in the art of subdividing the electric current.

Messrs. Sawyer and Mann, of New York, ob-

tained patents some years ago for a lamp based upon the exhaustion of a glass globe of air, and filling it with pure nitrogen gas, in which the incandescent material is intended to glow permanently. The light is produced by the incandescence of a slender pencil of carbon. The light-giving apparatus is separated from the lower part of the lamp by three diaphragms to shut off downward heat radiation. The copper standards of the lamp are so shaped as to give great radiating surface, so that the conduction of heat downwards to the mechanism of the base is wholly prevented. No detailed description of this lamp will be necessary, further than to say that the electric current enters from below, follows the line of metallic conductors to the burner, thence downwards on the other side to the return portion of the circuit. The light-producing portion is, of course, completely insulated, and also sealed at the base gas-tight.

A fatal defect in all previous lamps depending on incandescent carbon has arisen from what has been called the "vaporising" of the carbon. This Mr. Sawyer holds to be an absurdity, since the carbon is not even fused. The wastage of the carbon in mercurial vacuo and in atmospheres of compound gas is due, he maintains, to chemical decomposition. Many gases, indifferent to carbon at ordinary temperatures, attack it destructively at temperatures obtained in the electric lamp; and the process is continuous, the carbon taken

from the burner being redeposited on the glass case, and the gas left free to continue its depredation.

Mr. Sawyer claims to have overcome this difficulty by his method of charging the lamps with pure nitrogen gas only, and by providing for fixing of any residual oxygen left in the lamp. In this way it is claimed that an unwasting carbon is secured. Another stumbling-block, upon which many inventors have come to a standstill, has been the crumbling or disintegration of the carbon burner. This is usually caused by sudden heating when the lamp is first lighted. This is avoided in the Sawyer-Mann lamp by a kind of switch, with the use of which it is impossible to turn all the current on at once, or otherwise than gradually. This, however, the inventor holds, is not the only nor the chief advantage of the switch. It is claimed to be the key to the entire problem of practicable electric distribution.

A dynamo-electric light company has been formed in America to supply lights upon the Sawyer-Mann system, and they claim for it the following advantages:—It is well known that an electric current will exactly and readily divide among circuits of equal resistance; accordingly, if the resistance of a sub-circuit be maintained constant, no matter what may be going on in it, whether a lamp is not lighted at all or lighted to a mere taper, or to any intermediary stage up to full brilliancy, it is obvious that no other lamps in circuit will be affected.

The greater part of the illumination produced on this system is the product of a small part of the current. When the light is well on, a very slight increase in the current increases the light enormously. It is here that the great loss occasioned by dividing a fixed current among several lamps finds its explanation.

A current that suffices in one lamp to produce a light, say, of 100 candles, will, if divided between 2 lamps, give in each, perhaps, no more than 20 candles, or even 10, making a loss of 80 candles in the sum total. But if the current be doubled, each lamp will give a light of 100 candles, and the sum total will be 200 candles instead of 20. Having brought a carbon lamp or a system of such lamps up to the point of feeble incandescence, a (proportionally) small addition to the current will make them all brilliant. If at $6,000^{\circ}$ Fahr. a given carbon will produce a light of 3 candles, at $12,000^{\circ}$ Fahr. it will give 9 candles, and at $24,000^{\circ}$ Fahr. it will give 81 candles; the illuminating power increasing with vastly greater rapidity than the temperature. The wires supplying the current may be run through existing gas-pipes, each lamp being provided with a switch placed conveniently in the wall: and by simply turning a key the light is turned up and down, off or on. So long as the house is connected with the main, it makes no difference to the producer whether all the lights are on or off, since the existence of the entire house resistance remains the same; though a difference

will be caused to the consumer, since a meter records the time that each lamp is on, and the charge is rated accordingly.

When the main is tapped for a sub-circuit, a shunt is introduced so as to throw so much of the current as may be needed into the derived circuit. The resistance of, say, 100 added lamps will be about 1,000 ohms. By giving to the shunt a resistance of 10 ohms, 100th of the current will be diverted, and the lamps supplied. Where a large number of lamps are required in a circuit, a combination of two plans indicated is employed. The diversion of any portion of the electric supply into an added circuit, whether one house or a group of houses, necessarily increases the aggregate resistance of the electric district, and calls for more work from the generator. To meet such contingencies automatically, Messrs. Sawyer and Mann have invented and patented a regulator, which responds instantly to any increase or diminution in the demand, thereby securing an absolutely uniform volume of current.

This regulator so controls the steam or other power actuating the generator of electricity, that the amount of power supplied is increased or diminished in exact proportion to the demand, either by changing the volume of steam produced, or by coupling on or detaching different generators, or parts of a simple generator in circuit.

This system does not appear to have had an extended trial, and it is doubtful whether the

carbon pencils will be perfectly permanent. The light obtained by incandescent pencils is much less than that from the open arc with the same current, and the incandescent lamp is in this respect costly, even although a perfectly permanent pencil-lamp could be obtained. There is an obvious defect, too, in the Sawyer-Mann system when the resistance of the circuit, and consequently the expenditure, is always the same, whether the lamps are burning or not. This could, no doubt, be obviated.

M. Fontaine has likewise made many experiments with carbon pencils, but the best of them were consumed as usual in air in 15 minutes. Konn has also invented an incandescent lamp, in which a vacuum is maintained. Other inventors have also produced lamps of little use in practice.

Edison's First Lamps.

Mr. Edison's first experiments with the electric incandescent lamps, when regarded from the standpoint of conspicuous success he has now attained, are so full of interest that it will be well to retain the account of them given in this chapter in the first edition of the book.

Edison's first lamp (Fig. 104) was based upon a very old idea—the incandescence of platinum, which was employed by various inventors, and by King as early as 1845. All such lamps have so far been failures, and have proved wasteful of current, inasmuch as the true arc gives much more light for the same expenditure of power in the circuit; but the

worst defect was undoubtedly the unstable nature of the lamp. Edison's device, however, depended almost altogether for its usefulness upon an automatic regulator attached to it, and it has proved that automatic apparatus of this class work very indifferently. He employed, first, a strip of an alloy of platinum and iridium, A. This is fastened between two holders, the lower one of which is a lever, B, jointed at one end.

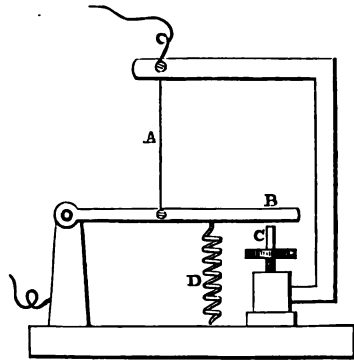


Fig. 101.—Edison's Platinum-Iridium Lamp.

This lever is provided with a spiral spring, D, constantly stretching the platinum-iridium strip, and under its end is a contact point, C. When the current passes the strip is made white hot, and gives out considerable light before it fuses. The expansion consequent upon this allows the antagonistic spring to put the strip out of circuit for an instant when it is in danger of being fused by the strength of current. Unfortunately, however, the expansibility of platinum is extremely small, and although the lever provided multiplies the expansion into a considerable movement, the platinum-iridium strip is very often fused before it can act. It is, in fact, extremely doubtful whether any regulator of current upon this principle will ever be devised.

It must not be forgotten, also, that any contact points in the circuit of a dynamo-electric machine will never work well. There is a powerful discharge of stored-up electric energy as soon as the circuit is broken, and what contact points will withstand such sparks? If there is to be regulation of circuit at all, it must be by means of some substance upon which pressure acts to increase or decrease the resistance, and not by open contact. It is, in short, at once apparent that the obstacles which stand in the way of inventing a useful lamp on this system are of a kind difficult of removal. The expansion of this lamp itself when it becomes heated would suffice to render useless any contacts or adjustments previously made. The apparatus is too delicate, and may be said to be useless in any but skilled hands. The idea of regulating the current has been tried in various pieces of apparatus intended to automatically govern the circuit of a dynamo-electric machine, and which are here spoken of under "Regulators of Current," p. 182.

Edison's first lamp was tried in England, but the results were anything but satisfactory, considering that it was originally intended to be applicable to general household purposes.

From private experiments made with Edison's apparatus, and modifications of it, the greatest care was found to be necessary to prevent the instant melting of the incandescent strip, and if the regulator is not adjusted with the greatest accuracy, the strip disappears under the energy in a twinkling.

Mr. Edison has also employed lamps made with platinum wire spirals, regulated again by expansion, and a break in the circuit. He also proposed the use of secondary currents, induction coils, and secondary batteries in circuit.

With regard to the platinum-iridium spirals for use in Mr. Edison's experimental lamps, a communication by the inventor himself, read before the American Association for the Advancement of Science, contains some interesting particulars of a new method by which they may be prepared for use in electric illumination.

In the course of his experiments on electric lighting he has developed some striking phenomena arising from the heating of metals by flames and by the electric current, especially wires of platinum, and platinum alloyed with iridium. The first fact observed was that platinum lost weight when treated in a flame of hydrogen, that the metal coloured the flame green, and that these two results combined until the whole of the platinum in contact with the flame had disappeared. A platinum wire, 20,000th of an inch in diameter, was wound in the form of a spiral one-eighth of an inch in diameter and half an inch in length. The two ends of the spiral were secured to clamping-posts, and the whole apparatus was covered with a glass shade. Upon bringing the spiral to incandescence for 20 minutes, that part of the globe in line with the sides of the spiral became slightly darkened; in five hours the deposit became so thick that the incan-

descent spiral could not be seen through the deposit.

This film, which was most perfect, consists of platinum, and Mr. Edison has no doubt but large plates of glass might be coated economically by placing them on each side of a large sheet of platinum, kept incandescent by the electric current.

This loss in weight, together with the deposit upon the glass, presented a very serious obstacle to the use of metallic wires for giving light by incandescence ; but this was easily surmounted after the cause was ascertained. He coated the wire forming the spiral with the oxide of magnesium, by dusting upon it finely powdered acetate of magnesium. While incandescent the salt was decomposed by the heat, and there remained a strongly adherent coating of the oxide. This spiral so coated was covered with a glass shade and brought to incandescence for several minutes ; but instead of a deposit of platinum upon the glass, there was a deposit of the oxide of magnesia. From this and other experiments Mr. Edison became convinced that this effect was due to the washing action of the air upon the spiral ; that the loss of weight and the colouration of the hydrogen flame was also due to the wearing away of the surface of the platina, by the attrition produced by the impact of the stream of gases upon the highly incandescent surface, and not to volatilisation, as commonly supposed.

He further describes other and far more impor-

tant phenomena observed in his experiments. If a short length of platinum wire, 1,000th of an inch in diameter, be held in the flame of a Bunsen burner, at some part it will fuse and a piece of the wire will be bent at an angle by the action of the globule of melted platinum; in some cases there are several globules formed simultaneously, and the wire assumes a zig-zag shape. With a wire 4,000th of an inch in diameter this effect does not take place, as the temperature cannot be raised to equal that of the small wire, owing to the increased radiating surface and mass. After heating, if the wire be examined under a microscope, that part of the surface which has been incandescent will be found covered with innumerable cracks. If the wire be placed between clamping-posts, and heated to incandescence for 20 minutes by the passage of an electric current, the cracks will be so enlarged as to be seen with the naked eye; the wire under the microscope presents a shrunken appearance, and is full of deep cracks.

If the current is continued for several hours, these effects will so increase that the wire will fall to pieces. This disintegration has been noticed in platinum long subject to the action of a flame, by Professor Draper. The failure of the process of lighting invented by the French chemist, Tessié-du-Motay, who raised sheets of platinum to incandescence by introducing them into a hydrogen flame, was due to the rapid disintegration of the metal. Mr. Edison has ascertained the cause of this phe-

nomenon, and has, he says, succeeded in eliminating that which produces it, and in doing so has produced a metal in a state hitherto unknown, and which is absolutely stable at a temperature when nearly all substances melt or are consumed; a metal which, although originally soft and pliable, becomes as homogeneous as glass and as rigid as steel. When wound in the form of a spiral, it is as springy and elastic when at the most dazzling incandescence as when cold, and cannot be annealed by any process now commonly known. For the cause of this shrinking and cracking of the wire is due entirely to the expansion of the air in the mechanical and physical pores of the platinum, and the contraction upon the escape of the air. Platinum, as sold in commerce, may be compared to sandstone, in which the whole is made of a great number of particles with many air spaces. The sandstone upon melting becomes homogeneous, and no air spaces exist. With platinum or any metal the air spaces may be eliminated and the metal made homogeneous by a very simple process.

This process is then described by Mr. Edison. He made a large number of platinum spirals, all of the same size and form and the same quality of wire; each spiral presented to the air a radiating surface of $3\frac{1}{16}$ of an inch; 5 of these were brought by the electric current up to the melting-point, the light was measured by a photometer, and the average light was equal to 4 standard candles for each spiral just at the melting-point. One of

the same kind of spirals was placed in the receiver of an air-pump, and the air exhausted to 2 millimètres ; a weak current was then passed through the wire to warm it slightly, for the purpose of assisting slightly the passage of the air from the pores of the metal into the vacuum. The temperature of the wire was gradually augmented at intervals of ten minutes until it became red. The object of slowly increasing the temperature was to allow the air to pass out gradually and not explosively ; after which the current was increased at intervals of fifteen minutes. Before each increase in the current the wire was allowed to cool, and the contraction and expansion at these high temperatures caused the wire to weld together at the points previously containing air. In one hour and forty minutes this spiral had reached such a temperature without melting that it was giving a light of 25 standard candles, whereas it would undoubtedly have melted before it gave a light of 5 candles had it not been put through the above process. Several more spirals were afterwards tried, with the same result. One spiral which had been brought to these high temperatures more slowly gave a light equal to 30 standard candles. In the open air this spiral gave nearly the same light, although it required more current to keep it at the same temperature. Upon examination of those spirals which had passed through the vacuum process, by the aid of a microscope, no cracks were visible : the wire had become as white

as silver, and had a polish which could not be given it by any other means. The wire had a smaller diameter than before treatment, and it was exceedingly difficult to melt in the oxy-hydrogen flame as compared with the untreated platinum. It was found that it was as hard as the steel wire used in pianos, and that it could not be annealed at any temperature. His experiments with many metals treated by this process have proved to his satisfaction, and he has no hesitation in stating, that which is known as annealing of metals to make them soft and pliable is nothing more than the cracking of the metal. In every case where a hard-drawn wire had been annealed, a powerful microscope revealed myriads of cracks in the metal. Since the experiment just mentioned was made, further investigations, with the aid of Sprengel mercury pumps, produced higher exhaustions, and by consuming five hours in excluding the air from the wire, and intermitting the current a great number of times, the result is stated to be the light of 8 standard candles from a spiral of wire with a total radiating surface of $\frac{1}{16}$ th of an inch, or a surface about equal to a grain of buckwheat. With spirals of this small size which have not passed through the process the average amount of light given out before melting is less than one standard candle. Thus Mr. Edison has been enabled, by the increased capacity of platinum to withstand high temperatures, to employ small radiating surfaces, and thus reduce the energy required for electric light.

He claims to have obtained 8 separate jets, each giving out an absolutely steady light, and each equal to 16 standard candles, or a total of 128 candles, by the expenditure of 30,000 foot-lbs. of energy, or less than one horse-power. As a matter of curiosity he made spirals of other metals, and excluded the air from them in the manner stated. Common iron wire may be made to give a light greater than platinum not treated.

Up to December, 1879, the outcome of Mr. Edison's praiseworthy labours to obtain a constant burner by electric agency, was a small lamp in the form of a glass globe exhausted of air, and containing in the electric circuit a horseshoe-shaped strip of carbonised cardboard.

This horse-shoe was stamped from "Bristol board," and was then placed in a wrought-iron mould and raised to such a temperature that the volatile constituents of the paper were driven off, the result being a miniature horse-shoe (2 in. long) composed of charred paper. Through this, when the containing globe has been exhausted by the air-pump, the current is passed from pole to pole by connections of platinum wire. It is claimed that this substance, which becomes highly incandescent and yields a brilliant light, is unchangeable by heat in vacuo, and that a lamp may be produced at an outlay of 25 cents.

A number of these lamps were seen burning in the inventor's laboratory by correspondents of the press, English and American, during the month of

December, 1879. The result was stated to be so satisfactory that Mr. Edison intended to illuminate, on a practical scale, the village of Menlo Park, and then to extend the system to New York.

There was little probability, however, that this lamp would prove constant. Carbonised paper in various forms had been repeatedly tried before, and it is probably not constant in the best possible vacuum obtainable. Moreover, the resistance of such a substance is very much greater than that of pure carbon in the graphite form.

Swan's and Edison's Lamps.

It has been said that carbonised paper had been tried as an incandescence burner before Mr. Edison employed that substance. Amongst others who had experimented in this manner was Mr. J. W. Swan, of Newcastle-on-Tyne, and it appears that both Mr. Swan and Mr. Edison were engaged simultaneously upon the same problem, with the same materials—carbonised paper—about the end of 1879.

Mr. Swan, after many experiments, extending over many years, appears to have first abandoned the use of carbonised paper, and to have resorted to cotton or linen thread, treated with dilute sulphuric acid, and afterwards carbonised in a closed crucible at a white heat. The result of Mr. Swan's experiments was a hard and elastic filament of pure carbon about 3 inches in length. It is made to describe a single convolution, and its extremities are

connected to two platinum wires. The filament is then inserted into a small glass globe, from which the air is extracted by long continued action with mercury air-pumps. When the highest attainable vacuum is obtained, the connection with the interior of the globe is fused up, the result being the arrangement exhibited in Fig. 105. The platinum wires terminate in two small loops as represented. These are readily attached to or removed from the electrical connections of a small ebonite socket,



Fig. 105.—Swan's Lamp.

shown in Fig. 106. The spiral spring represented serves to receive the base of the globe, and to press the lamp away from its socket, so that the metallic contact between the loops in Fig. 105, and the two small hooks in Fig. 106, may be as perfect as possible. The carbon thread or wire employed by Mr. Swan is as elastic as steel, and is considerably thinner than the black line shown in the diagram.

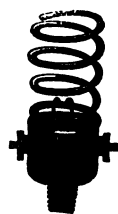


Fig. 106.—Socket for Swan's Lamp.

When the current passes the carbon wire becomes incandescent, and emits a beautiful white, silent, and steady light. The vacuum attained in the lamp is so perfect that, instead of being wasted away, the filament becomes more dense by use. In course of time, however, there appears to be a gradual wasting away of the carbon wire at

the positive end, and probably an increase of diameter at the negative extremity. If the current is much too strong, the lamp may be destroyed in a very short time ; but if the current is only a little over the normal strength used for the lamp, a disengagement of the particles composing the carbon wire ensues, and in the course of time the interior of the globe may present a smoked appearance. This agrees with the results of Mr. Edison's experiments with the platinum spirals. When the lamp is worked by the current suited to its powers, the "life" of the carbon wire varies from 700 to perhaps 3,000 hours. Hence, a lamp of this description may serve for ordinary purposes for many months, or a year, burning nightly. The "life" of the lamp varies, however, to a great extent ; and it is difficult, if not impossible, to assign a limit, with any show of reason, to the time one of the carbon loops may last. When alternating currents are used it is probable that, since there will result no wasting away at either extremity, the life of the carbon loop may be indefinitely extended. The cost of the lamp is very small. They are made of from 5 to 100 candle power, according to the length of the carbon loop employed. The 18-candle power lamp is, however, the most generally useful. The resistance of this lamp is about 150 ohms when hot. When cold it is considerably greater, probably 250 ohms. These lamps are now a regular article of commerce. They are adapted for fitting to existing gas-brackets. One insulated wire being

led to the lamp, the return may be effected through the gas-fittings if required. Swan's lamps have been in constant use at the Savoy Theatre, in London, since the end of 1881. About 1,158 of these lamps are used to illuminate the whole of the auditorium and the stage in this installation, of which further particulars will be given in the chapter on Circuits.

Mr. Edison also abandoned the use of the carbonised paper, and after numerous experiments, and the testing of grasses or fibres brought from various parts of the globe, he used a kind of bamboo. Lately, we understand, the South American grass known as "monkey bast" has been employed by Mr. Edison. The filaments are divided and sub-divided until they are sufficiently thin to form a single carbon wire. They are then curved upon a former of graphite or plumbago to the shape of a long U, and carbonised in the usual manner. The result is a carbon wire similar to that employed by Swan. It is attached by electro-deposits of copper, and by other methods, to a pair of platinum wires, which lead out through the glass base of a pear-shaped bulb. The result is a lamp similar to that already described, and is carefully exhausted of air by means of mercurial air-pumps. The neck of Edison's lamp carries a metallic screwed plug, intended to fit into a socket. This portion communicates with one of the platinum wires. The other wire is connected to a central metal stud, insulated from the collar. When the

arrangement is screwed into its socket, contacts are made with the necessary leading wires. A circuit-interrupting key is provided, by means of which the circuit may be closed or opened at will. Fig. 107 represents Edison's lamp about half real size.



Fig. 107.—Edison's Lamp.

In all other respects Edison's lamp is similar to Swan's. It is made in several different light-giving powers, but the lamp in general use at present is intended to yield a light of 16 candles, so that it may be made to take the place of ordinary gas jets. The resistance of this lamp when cold is 220 ohms. When hot it is reduced to 140 ohms. An important installation of Mr. Edison's system was made at the Holborn Viaduct, London, in April, 1882. In this instance about 950 of the Edison lamps are distributed over the thoroughfare and the shops of the Viaduct. The whole is maintained by a single 1,000-light

dynamo machine of Edison's design. In the city of New York a large installation of this system has recently been brought into use, and several thousands of the incandescence lamps are maintained by a number of 1,000-light machines, as in the above instance.

Mr. St. George Lane Fox has also invented an incandescence electric lamp similar in design to

that of Edison. Mr. Fox employs a carbon wire made from flax or cotton thread, also the root of the grass known as "French whisk." When carbonized, this thread is mounted, and rendered incandescent in coal-gas and benzoline, which completes the carbonization. The glass bulbs are carefully exhausted by means of mercury pumps.

Mr. Maxim, of New York, was among the first who employed carbon in the form of a filament for incandescent lighting, and his lamps have been in extensive use. In this case the filament is formed into a shape like the letter **M**. Fig. 108 represents Mr. Maxim's lamp, which is in other respects similar to those of Edison and Swan. It has been in use in the New York Post-Office, and it is said that the "life" of each lamp varies in this instance from 1,000 to 3,000 working hours.



Fig. 108.—Maxim's Lamp.

Several other inventors have produced incandescent lamps. Many modifications of those already described have been published. One inventor forms a hollow carbon filament or tube by depositing carbon upon a fine wire of platinum, and deflagrating the platinum. Another deposits carbon upon an infusible insulating filament.

CHAPTER IX.

ON CIRCUITS.

WITH regard to the conduction of the current from the machines to the points where the light is emitted, some of the arrangements employed for the purpose by Messrs. Siemens Brothers and the Brush Electric Lighting Corporation, and the other leading companies, may serve as examples.

The current generated in the machine is conducted through a leading wire to the lamp or lamps; it passes in the lamp (in the case of an arc light) from one carbon point to the other, thereby producing the electric light, and returns through another wire (the return wire) to the machine. These two wires are usually known as "leads" and "returns." Mr. Massey, electrician to the Electric Light and Power Generator Company, recommends the adoption of these terms by electrical engineers generally, it being understood that the "lead" is to be connected to the positive (+) terminal of the dynamo machine. He further recommends the general adoption of an uniform method in laying the leading and return wires, by placing all "leads" to the left hand (looking from

the machine towards the lamp), and all “returns” to the right.

This complete circle is called the outer (or exterior portion of the) circuit, and when it is unbroken and continuous it is said to be *closed*; if in any one part an interruption of continuity occurs, it is said to be *open*.

Leading Wires are manufactured of strands of copper wire, and are either naked or coated (insulated). Naked wire is preferably used for the return wire, and it is only when used as a return wire that it should be allowed to touch the earth. In some cases naked wire may also be used to lead the current to the lamps, but in such cases it must invariably be insulated from the earth by being attached only to porcelain or other insulators attached to walls, poles, or trees. No other wire or mass of metal—save binding-wire—must touch such a conductor, otherwise there is danger of leading off the current back to the machine or to the earth before it reaches the lamps. Coated or insulated wires are covered throughout their length by an insulating substance, such as gutta-percha, or india-rubber and tape.

Where it is carried through rivers or lakes, or buried underground, the coated leading wire receives a further protecting covering of iron wires against external injury.

The following are some of the more frequently employed leading wires (Siemens' system):—

Leading Wire No. 90, Fig. 109, consisting of 7 copper wires, insulated with tape and india-rubber

to a diameter of about 0.34" (= 8.5mm). For a distance of not more than 450 yards between machine and lamp, and a total length not exceeding 900 yards of wire.



Fig. 109.—
Section of
Insulated
Leading
Wire.

Plain copper strand of same diameter as in the above.

Leading Wire No. 180, Fig. 110, consisting of 14 copper wires, insulated with tape and india-rubber to a diameter of about 0.44" (= 11.2mm). For a distance of not more than 900 yards between machine and lamp, and a total length not exceeding 1,800 yards of wire.



Fig. 110.—
Section.

Plain copper strand of same diameter as above.

Leading Wire No. 240, Fig. 111, consisting of 19 copper wires insulated with tape and india-rubber to a diameter of about 0.48" (= 12.2mm). For a distance not exceeding 1,200 yards between machine and lamp, or a total length of not more than 2,400 yards:

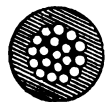


Fig. 111.—
Section.

BRUSH SYSTEM.

Machine Nos. 1 & 2	Approximate Equivalent in	
	Solid Wire.	Stranded Cable.
	No. 8 B.W.G.	7 strands of No. 16s B.W.G.
3	7 "	" " "
4 (a)	8 "	" " "
4 (b)	8 "	" " "
4 (d)	3 "	7 strands of No. 13s B.W.G.
5 (a)	7 "	7 strands of No. 16s B.W.G.
5 (b)	8 "	" " "
6	8 "	" " "
7 (a)	8 "	" " "
7 (b)	" "	" " "
8	8 "	7 strands of No. 16 B.W.G.

NOTE.—The resistance of one mile of 7 No. 16s is approximately 2.2 ohms, and every two miles of circuit with wire of this size may be considered equivalent to the insertion of an additional 2,000 c.p. lamp.

Cotton-covered wire of Nos. 12 or 14 B.W.G. is frequently used for conducting branches for groups of the incandescence lamps, and Nos. 16 and 18 may be employed for single lamps. For branches exterior to a building it is advisable to use the same wires insulated with india-rubber and covered with a protecting layer of tape saturated with india-rubber.

Figs. 112 to 114 represent some of the more



Fig. 112.—Connecting Single-wire Conductors.

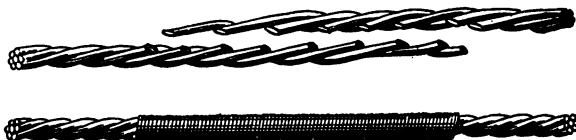


Fig. 113.—Twisted Wire Joint.

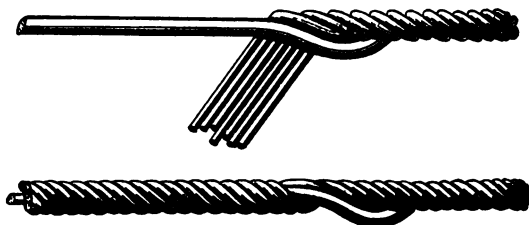


Fig. 114.—Connection between Stranded and Single Conductor.

useful wire and strand joints as used by the Brush Company. Each joint is intended to be soldered. Fig. 115 shows a connecting piece. Fig. 116 shows Clark's joint. In leading the wires it is particularly

to be observed that the "lead" and "return" do

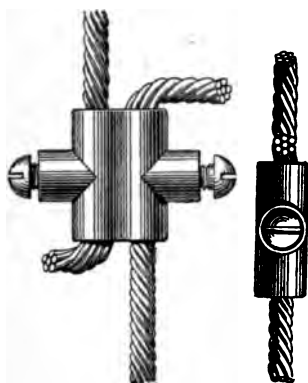


Fig. 115.—"Coupling-piece" for Leading Wires.

not come into contact. In most cases the wires should be kept apart to a regular distance. Six inches may be considered the minimum of safety, unless the electromotive force of the machine is very low. The dryest route should always be selected in leading the wires. In permanent in-

stalments the wires should be fastened down to floors or walls. In no case should metallic staples



Fig. 116.—Latimer Clark's "Britannia Joint."

be used for this purpose. Leather tapes are the most suitable fasteners. They should be employed after the manner indicated in Figs. 117 and 118.



Fig. 117.—Tape Wall-fastening for Leading Cable.

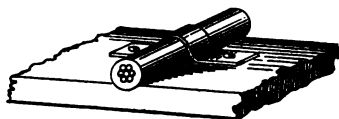


Fig. 118.—Floor-fastening.

In such cases small nails may be used if kept away from the wires.

Abrasion of the wire coverings should be particularly avoided. They should therefore be placed

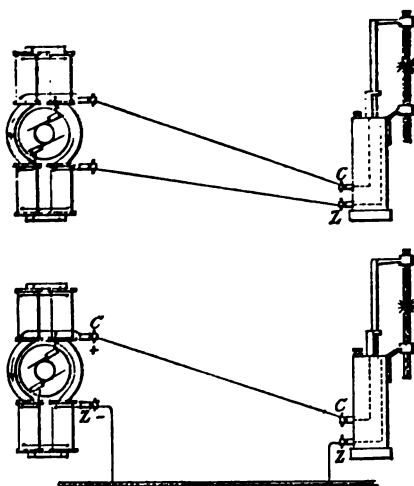
in an undisturbed position, and as little slack as possible should be allowed.

The leading and return wires present a certain resistance to the current. The resistance is less as the wires are larger; it is, in fact, inversely proportional to the sectional area of the wire, and directly as its length. The leading wires should always offer as small a resistance, compared with the source of light, as possible. The resistance is generally expressed in terms of the unit known as the ohm, which is approximately equal to the resistance offered by 210 feet of No. 16 B.W.G. of pure copper wire. In the usual form of electric lighting circuit, the resistances are those of the machine, leading wire, lamp (or lamps), and the return wire. When these are added together they are spoken of as the *total* resistance. Resistances are generally determined by means of a Wheatstone's Bridge and a case of resistance coils, by methods expressed in text-books of electricity.

General Circuit Arrangements.—This branch of the subject naturally divides itself into two great sections, namely, circuits for electric lighting by the arc system and those employed for the incandescence system. In order to elucidate the general arrangements employed with the arc system, we may select one kind of machine and lamp, namely, Siemens', and offer a few remarks concerning them.

In the case of a single machine and a single lamp, the connections between them are easily

understood. The leading wire is connected to the positive terminal of the machine (generally marked C or +), and leads to the upper carbon of the lamp (generally marked C). When a "return" can be



Figs. 119 and 120.—Circuits for Single Arc Lights.

effected through gas or water pipes, or other continuous conductor of large size, the return wire may be dispensed with. Those two methods of arranging the connections are represented in the diagrams, Figs. 119 and 120 respectively. The return wire leads the current from Z of the lamp (the lower carbon) to Z of the machine, or its negative terminal (frequently marked —). When the machine is driven in the right direction, those connections will cause the current to flow from the upper carbon to the lower. If the upper carbon should not burn hollow, but pointed, the polarity of the machine

may be assumed to have become reversed, causing the current to flow in the wrong direction through

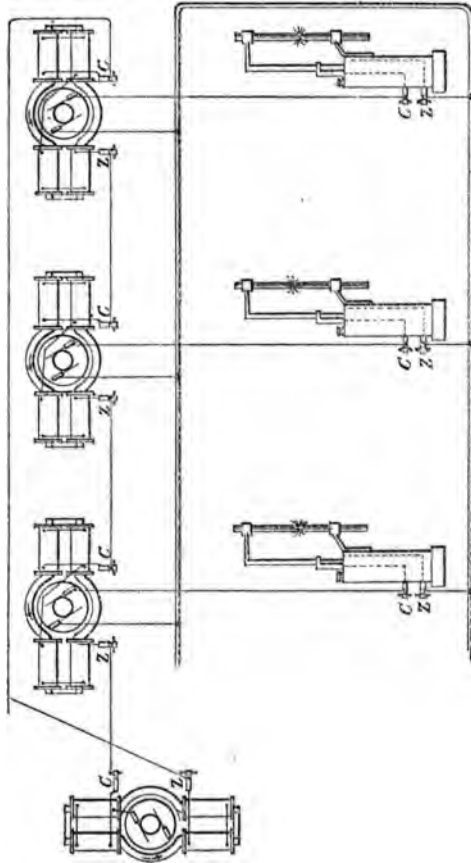


Fig. 121.—Arc Lighting Circuit Arrangements, with separate Exciter Machine.

the lamp. In such case the wires at either machine or lamp should be attached to reverse terminals.

When several continuous-current machines are

arranged to burn an equal number of arc lamps, it is found advantageous to add one more machine beyond the number of lamps to be fed, and use this machine to excite the electro-magnets of all the others. In such case terminal C of the exciting machine is connected with one extremity of the magnet coil of the first light-giving machine, and the other end of this wire with the commencing end of the electro-magnet of the second light-giving machine, and so on with the others until the extremity of the electro-magnet coil of the last machine is connected with z terminal of the exciting machine.

The right-hand "combs" or collectors of the light-giving machines, representing their positive poles, are to be connected to the terminals C of the respective lamps. The left-hand combs and the z terminals of the lamps are thus connected to a common return wire. This arrangement is represented in the diagram, Fig. 121.

When the currents employed are alternating, and the Siemens' alternating current machine is used, the following connecting arrangements are necessary:—A small continuous-current machine, as shown in Fig. 122, is used to excite the field-magnets of the alternating-current machine; its terminals are connected with the extremities of the field-magnet coils of the large machine (lower terminals). The terminals on the contact rings of the alternating-current or large machine (upper terminals) consist of the black or "return" terminal,

and of brass terminals equal in number to the circuits which the machine is constructed to work. The lamps are divided into as many groups as there are circuits, putting an equal number of lamps into each. The connections in each group of lamps are made as follows:—

One brass terminal on the contact rings of the machine is connected to each group. The connection leads from the

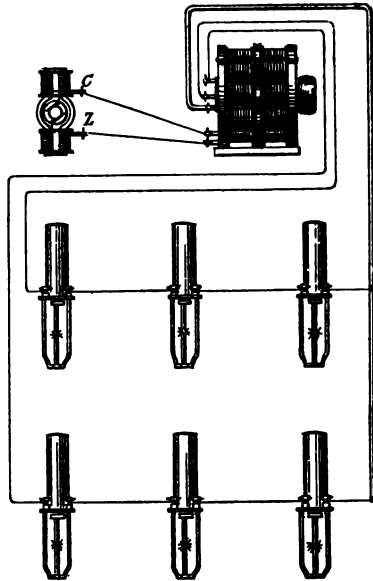


Fig. 122.—Circuit Arrangements for Siemens' Alternating Current Arc System.

brass terminal to first terminal of first lamp: from second terminal of first lamp to first terminal of second lamp, and so on until the second terminal of last lamp leads to the common return wire. The black terminal on the main machine is also connected to the common return wire.

When it is desired to open the circuit, whether in the case of continuous-current or alternating machines being used, the machine should, if possible, be stopped first, otherwise the "extra current" evolved by the sudden rupture is very apt to injure the insulation of the machine. It is better

to open the circuit by drawing away the carbons in the lamp than to disconnect either of the leading wires.

Accessories, Resistances, etc.—Arrangements known as “bar commutators” are generally used in connecting several machines to several lamps, so that the lamps as well as the machines may become interchangeable among each other. They consist of a series of parallel metal bars placed above and insulated from a second series of metal parallel bars, in such a manner that the upper series run at right-angles to the lower series. The lower bars are furnished with terminals which receive the leading wires from the machines. The upper bars have also terminals which receive the leading wires from the lamps, resistances, &c.

The current being led from the machine arrives at the bar to which the wire is attached. Its progress is arrested at this point. When it is required to transmit the current to a particular lamp, a metal plug is inserted at the point where the bar connected with the lamp and the bar connected to the machine intersect. The current then flows through the plug from the lower to the upper bar, so completing the circuit. In cases where screws are used instead of plugs, care must be taken not to attempt to open the circuit at the bar commutator while the machine is in motion. If one of the screws be withdrawn under those conditions, a voltaic arc will be formed at the breach, and will begin to consume the upper bar and

the plug. This arrangement is represented in Fig. 123.

Resistance Controllers.—When an arc lamp or lamps are withdrawn from the circuit, the resistance of which should remain constant, an arrangement termed a “resistance frame” is inserted. This consists of a number of helices of iron wire so attached to connectors that one or more of the helices may be inserted into the circuit, according to the resistance required. Zig-zag lengths of iron tape are employed for the same purpose, and carbon rods have been much used by Messrs. Siemens. When the whole current is so passed through the resistance, much heat is developed, and in the case of employing helices of wire they should be exposed to the cooling influence of the air as much as possible. In some arrangements they are immersed in water. In Edison’s system of lighting by incandescence, the resistances consist of copper wires wound around hexagonal or square frames, and freely exposed to the air. In this system, however, only a portion of the current that shunted into the field-magnet is transmitted through the artificial resistance.

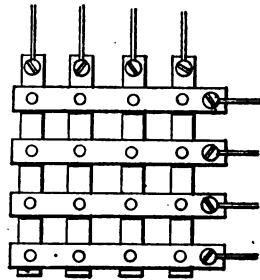


Fig. 123.—“Bar Commutator.”

The resistance arrangements employed in the Siemens systems of arc lighting usually consist of carbon rods placed side by side upon a board, and

connected with each other in such a manner as to create one continuous length of conductor. In

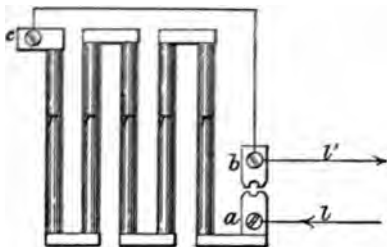


Fig. 124.—“Artificial Resistance.”

Fig. 124, r r represent the carbon rods; a b c are terminals. The leading wire into the circuit of which the resistance is to be placed is connected to the terminals

a and b ; b is further connected by a short thick wire to c . If the plug between a and b be inserted, the current will flow through a and b , and no resistance will be added to the circuit; but if the plug be removed, then a will be separated from b , and the current must traverse each one of the carbon rods in succession. These resistance arrangements are constructed to suit the circumstances of each case.

In some cases it is found better to shunt a portion of the current through a resistance coil attached directly to the two terminals of the machine. In lighting by incandescence, the current from the armature is almost invariably controlled by weakening and strengthening the current exciting the field-magnets; for this purpose iron wire coils are generally used. The latter method is the more economical, because, if a lamp be abstracted from the main circuit (in the former case) and a resistance equivalent to it be inserted, the same energy

is required to maintain the circuit as before, and the current is wasted in heating the resistance. In the latter case the current is generally small, and by inserting a resistance into the field-magnet circuit the amount of energy wasted in heat is practically inappreciable.

Siemens' Deviator.—This arrangement serves to substitute itself in an arc lamp circuit for a lamp which has accidentally become extinguished. It is a crude form of electric lamp, and indicates by the light it suddenly sends forth when beginning to act that the circuit to which it belongs has been severed or the lamps extinguished.

It is arranged according to the method represented in Fig. 125. E is an electro-magnet. It is wound with thick wire. One extremity of its coil is connected to the metal frame F, and the other to the terminal M. A is an armature sliding between guides, and bearing the upper carbon rod C, and pushed by the spring s, through

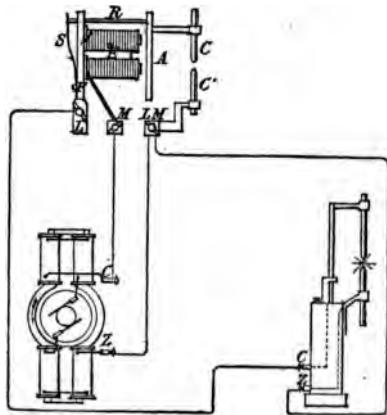


Fig. 125.—Arrangement of Siemens' "Deviator."

the rod R, away from E. F, and through it R, A, and C, are in contact with terminal L. The

lower carbon rod, C^1 , is connected with terminal L M. The machine is connected to terminals M and L M; the lamp to L and L M. When the current passes through the lamp its course is as follows:—C terminal of machine, terminal M, E, F, terminal L, lamp-terminal L M, Z terminal of machine. Thus the circuit is closed. In its passage through E the current makes E magnetic, attracts A, and separates C and C^1 ; thus, when the current passes in the proper circuit the deviator does not burn.

Circuits at the British Museum.—The Reading-room is illuminated by four inverted pendulum lamps, each lamp being fed by a separate dynamo-electric machine of the type D₂. In the corridors, the offices, staircases, and the engine-room, sixteen differential lamps are fixed, also forty-seven Swan incandescent lamps. The differential lamps are fed by an alternating current machine of the type W₂. Another machine of the same kind and size feeds the incandescent lamps. The four lamps of the continuous current circuits are directly connected to the machines, one common return wire serving for all four. The differential lamp circuits are arranged as follows:—In one circuit eight lamps are placed, and one artificial resistance. In the other also eight lamps are placed, but as these lamps are not always all burning, three artificial resistances are provided. By means of commutators, either one, two, or three resistances can be put into circuit, one resistance being commonly used for every two lamps withdrawn from work.

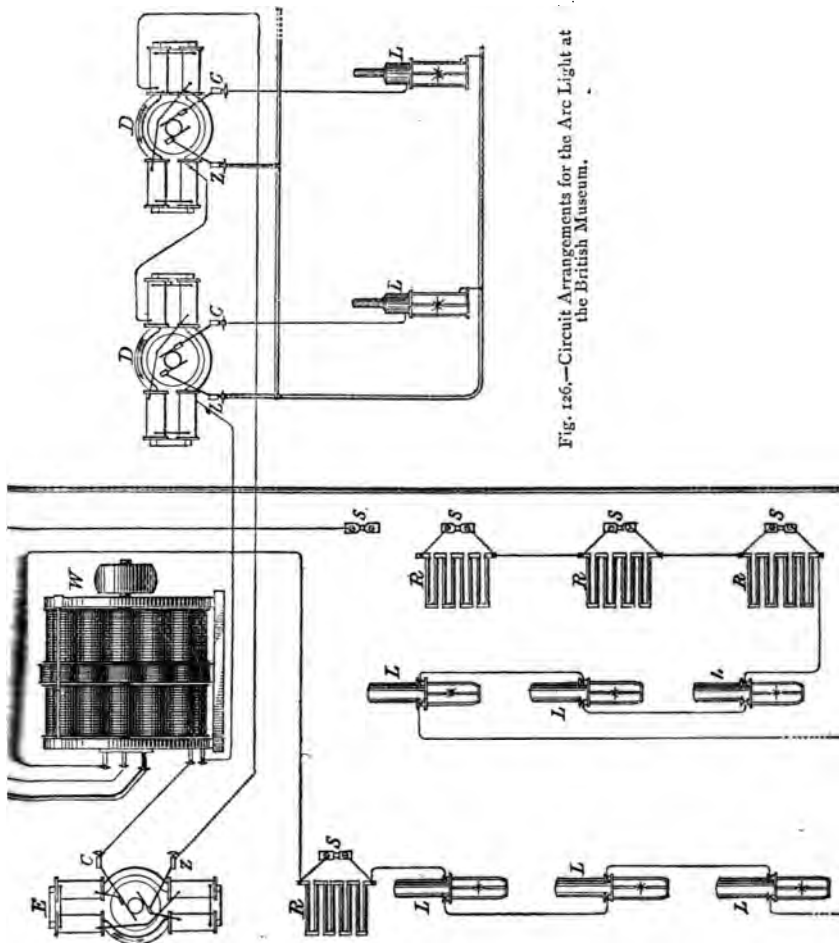


Fig. 126.—Circuit Arrangements for the Arc Light at the British Museum.

The diagram (Fig. 126) shows the circuits of this installation, with the exception of the incandescent lamp circuits, which have been added only recently. E shows the separate exciter, w the alternating-current machine, D D the continuous-current machines, R R R the resistances, L L L the lamps, and S S S S the commutators. The continuous-current lamps are approximately of 3,000-candle power each, suspended at a height of about 30 feet from the floor. The alternating-current or differential lamps are of 300-candle power, fixed at 15 feet above the floor. The forty Swan lamps are of 16-candle power each. The whole of the machines by driven by two 8 H.P. (nominal) semi-portable steam-engines.

Circuit Arrangements at the Royal Albert Dock, London.—The area illuminated is about 9,000 feet long and 1,500 feet wide. The lighting is done by 27 inverted pendulum lamps, each one fed by a separate D_2 dynamo (Siemens') machine. The machines are distributed in four stations of seven, seven, seven, and six light-giving machines respectively. In each station an additional machine is used to excite the electro-magnets of the light-giving machines. The c terminals of the light-giving machines are connected to the lower bars of a commutator, the upper bars of which are connected through deviators (previously illustrated) to the lamps. All the z terminals and lower carbons of deviators and lamps are connected to the common return wire. An electro-dynamometer is joined with

the commutator, so as to allow of the measuring of the current in any one lamp-circuit. In the diagram (Fig. 127) E shows the exciter, D D D are the

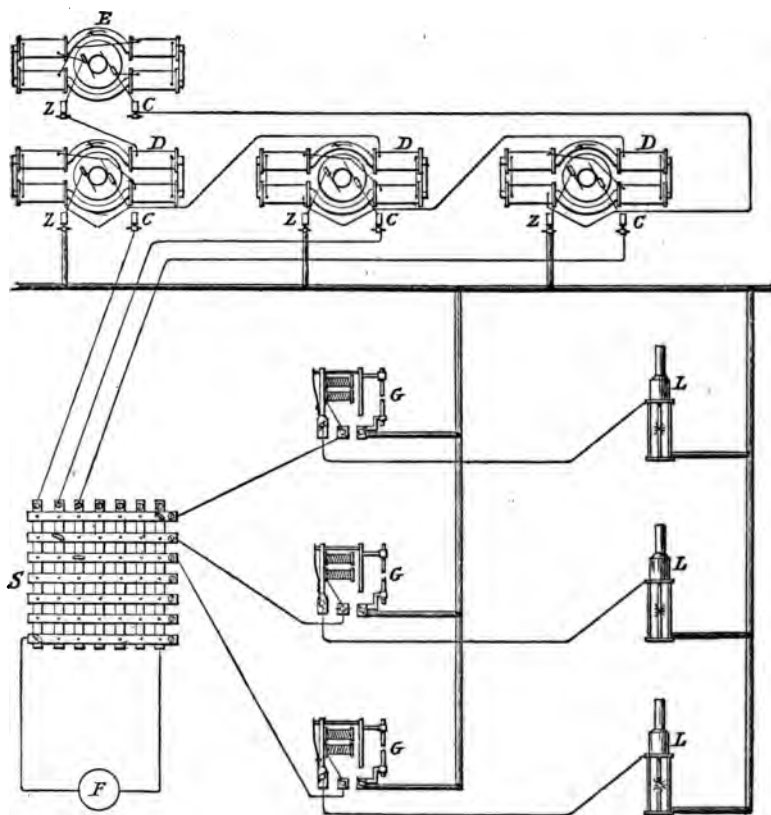


Fig. 127.—Circuit Arrangements at the Royal Albert Docks.

light-giving machines, S is the commutator, F the dynamometer, G G G the deviators, and L L L the lamps. The lamps are suspended from lattice iron

poles at a height of 80 feet above the ground. Each machine station is provided with a 20 H.P. (nominal) steam-engine. Besides these arrangements the dock-sheds have lately been fitted with alternating-current lamps of 300-candle power, which are adapted to extended circuit wires, so that any one lamp may be shifted to any particular part of the sheds.

Circuit Arrangements for Incandescent Lighting.—The method practically adopted for the feeding of incandescent lamps is almost invariably that known as multiple arc or connection in parallel circuit. According to this method, in its simplest development, two wires are led from the electric source; they are kept apart. The incandescent lamps are then connected so as to bridge across from one wire to the other. In Edison's system only one lamp is so placed to form one particular bridge; the arrangement thus consists of a large number of single lamps acting as bridges from one electrical main to the other. It is found that when the Edison lamp offers a resistance of 140 ohms when hot, an electromotive force from the machine, or, in other words, a difference of potential between the electrical mains of 110 volts, suffices to maintain the lamps when thus made to bridge the mains singly.

But when the lamp presents a much smaller resistance, or (using the same lamp) when the machine develops a much larger electromotive force, it is found more economical to arrange the

lamps in series of two or more, instead of singly, to bridge across the mains. This is frequently done with the Swan lamps and the Siemens machines. The number of lamps to be attached in series depends obviously upon the difference of potential between the mains, and upon the resistance of the lamps.

When two long wires are led as mains from a machine, and the lamps simply bridged across, regardless of distance from the machine, it is found that the lamps nearest to the machine are brighter than those farthest from the machine. Hence, it will be found that the lamps at the extremities of two long mains would receive very little of the current, whereas those near the machine would be served with too much current. This difficulty is met by not attaching the machine to the two extremities of the mains as described, but more generally to their central portion, so that the current is more evenly distributed throughout the lamps, and branches are also frequently taken from the machine, so as to lead a due proportion of the current to parts of the mains which would otherwise not receive a due proportion.

This difficulty is analogous to that which would be encountered were we to lead a long gas-pipe carrying a moderate quantity of gas, and to fix upon it at intervals a large number of burners. Those burners nearest to the supply end would consume or be supplied with too much gas, while those at the farthest end would not be supplied with the

required quantity. If, however, we were to arrange the burners in groups, upon branches from the main, the difficulty would not be so great to maintain each burner.

In the same manner, a given number of incandescent lamps can be more impartially maintained by arranging them in groups (or series of two or more) between the mains, when sufficient electromotive force is developed for that purpose. In Edison's system, where one lamp only is allowed to bridge across the mains, "feeders," or auxiliary leading wires are so distributed that no portion of the parallel circuit can be supplied with more of the current than any other portion. It would appear that, although this method allows of several lamps being lighted or extinguished without sensibly disturbing the brightness of the others, the increased cost of laying leading wires for purposes of equal distribution would be greater than that of feeding the lamps in series of two or more, and so dispensing in a great degree with supplementary mains.

The "safety fusible plugs" employed in the Edison and Swan systems usually consist of a short length of lead wire. Their function is to melt and so sever the branch of the circuit in which they are placed, should an unduly strong current, by any accident, be transmitted into that branch.

Siemens' Electro-Dynamometer.—This instrument (Fig. 128) is generally used for measuring the current from either continuous-current or alter-

nating-current machines. It consists of a wooden frame placed on three levelling screws. On the lower (horizontal) part of the frame three terminals are arranged; to the upright part a fixed coil of two insulated copper wires is attached, and to the upper end of the frame a disc with a movable

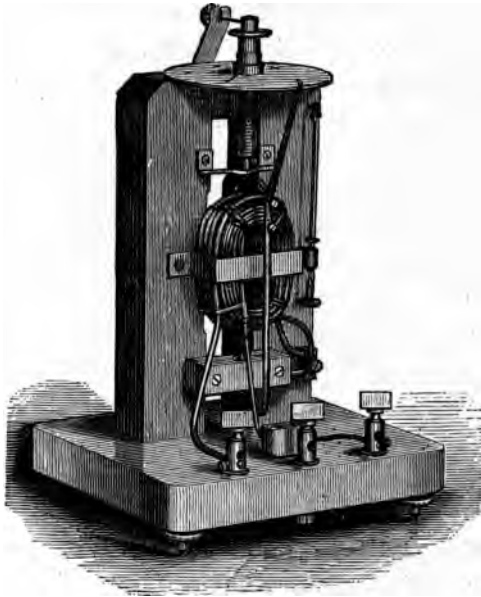


Fig. 128.—Siemens' Electro Dynamometer.

axis. The circumference of the disc is divided into degrees. The two wires of the fixed copper coil are connected each with one end to a terminal and with the other end to a mercury cup. The two wires are of unequal thickness, the stout one being connected to terminal 3 and the mercury cup and the thin one to terminal 2 and the cup. From the

axis of the disc hangs on a fine spiral spring a movable loop of stout copper wire, which dips with one end into the mercury cup and with the other into a second mercury cup below the first one. This second mercury cup is connected to the central terminal.

The loop bears an index arm reaching up to the circumference of the disc. The movable axis from which the loop is suspended bears a pointer, which is fixed to it by a collar and a small screw. The top of the axis has a screw head. A plumb-bob attached to the frame serves to place the instrument in a perpendicular position. A small horizontal axis with screw head in its outer end, and resting on the larger movable axis with its inner end, holds the suspension of the copper loop, and by turning it one way or another the copper loop is lifted so as to move freely, or let down so as to rest immovably.

For use, place the instrument on a firm basis, put it into a position that the plumb-bob will hang perpendicularly, lift the loop to move freely, and see whether the index arm on the copper loop and the pointer from the axis both point to zero on the disc. Should they not do so, turn the vertical axis until the index arm does, and then loosen the screw on the collar of the pointer and turn the pointer until it also rests on zero, then screw the pointer fast again. The wires of the circuit, the current of which is to be measured, are connected in the case of a dynamo circuit to—

Terminals 1 and 3,
in that of an alternating current circuit to—

Terminals 1 and 2.

The current then enters (say) at terminal 3, passes through the stout wire of the fixed coil into the upper mercury cup, through the movable copper loop into the lower mercury cup, and leaves at terminal 1.

While passing, the current makes the loop turn from its position of rest, and its index arm therefore leaves the zero on the disc. The movable axis must then be turned until the index arm has returned to zero, and the angle through which the axis has been turned is shown by the pointer on the disc.

If several currents are measured by this instrument, they bear the same proportion to each other as the square roots of the respective angles observed.

A table at the back of the instrument gives the constants to be used for calculating from the angle the current in ampères. These constants hold only good, however, for the particular spiral spring which was in the instrument when the constants were determined.

CHAPTER X.

MEASUREMENT OF ELECTRIC LIGHT.

PHOTOMETRIC measurements, as applied to the light produced by electricity between two carbon points, are not so easily obtained accurately as may be supposed. The value is usually given in terms of comparison with the standard sperm candle, burning, as nearly as possible, 120 grains per hour.

London gas, with a burner consuming about 5 cubic feet of gas per hour, gives an average illuminating power of 15 standard candles, Liverpool gas 16; and the gas of other towns varies in quality so greatly that gaslight should never be employed as a standard of measurement unless its actual value has been determined. In France the measurement is usually made by comparing with the light of a Carcel lamp, burning 648 grains of pure oil per hour. An ordinary gas jet, burning $4\frac{1}{2}$ cubic feet per hour, is equal to $\frac{1}{10}$ th of a Carcel light as above. A burner consuming 7 feet per hour is equal to 1.72 Carcel lights—taking 16-candle gas.

The intensity of the beam of electric light varies considerably according to the relative positions of

the carbons. Thus, if a carbon having a square section be placed so that its axis corresponds with the line of one of the angles of the other carbon, the beams of light in different directions will vary as much as the ratio of 38 to 287, and even when the axis of one carbon lies properly in a prolongation of the axis of the other, the beam will vary with the angle formed by the beam with the axis of the carbons. Thus it is stated that the beam at right-angles to the axis has measured 970 candles only, whilst that measured at 45° with the axis of the carbons has been 2,000 candles. The light should, therefore, always be measured on a beam at right-angles to the axis of the carbons.

Rumford's Photometer is one of those often used, and its simplicity recommends it to the practical electrician. It consists simply of a calico or other screen, in front of which, and about a foot from it, is placed, vertically, an opaque rod of any material, such as blackened wood. The lights to be compared—for example, a candle and a gas-jet—are placed at different distances from the rod, and the gas-jet is moved until the shadow it casts from the rod upon the screen is equal in intensity to that produced by the candle, which will, of course, be much nearer to the rod. The intensity of a light diminishes as the square of the distance increases, or in other words, *the intensity of the light is inversely proportional to the square of the distance*. Since the intensity of a light at twice the distance is one-fourth, and at three times the distance one-ninth, it

is obvious that if two sources of light, of which one is placed at a certain distance from a surface while the other is placed at a distance twice or three times as great, produce equal degrees of illumination, the illuminating power of the more distant light must be four or nine times as great compared with the illuminating power of the light which is nearer to the surface. From this it is clear that when two sources of light produce equal intensities of light upon two surfaces at unequal distances, their illuminating powers are in the ratio of the square of their distances from the illuminated surfaces.

Unfortunately, a difficulty is introduced in such work by the redness of a candle light and the intense violet rays given off by the electric arc light. For electric arc light measurements it is found better to use Bunsen's photometer, which enables the intensities to be compared with greater accuracy than is possible by the use of the opaque rod and screen. The difficulty consists in the very different appearance presented by a shadow cast by the reddish candle, and that given from the brilliant electric light.

Bunsen's Photometer consists of a square wooden frame, over which is stretched a piece of white paper having a circular grease-spot in the centre. When lights are to be compared, a straight line is drawn upon a flat surface, the paper screen is placed vertically upon it with its centre on a level with the two lights, which are arranged upon either side of

it. The stronger light is moved away upon the line until the grease-spot is not visible, and then as before, by measuring the distances between the lights and the screen and comparing them, the power may be determined with considerable accuracy. A wax-spot is best made by dropping melted stearine upon the paper, removing it with a knife, and weakening the strength of the spot by passing blotting-paper on either side of it under a hot iron. If the spot be too strong, it will be difficult to arrive at correct estimate of the values.

Equal advantages should be given to both lights. For example, if the electric light be thrown upon the screen from a parabolic reflector, the candle-light should be also provided with a similar backing. If the electric light be diffused, the candle light should also be diffused, and care is necessary to have the back-grounds and sides near to the lights equal in colour or reflective power. Care is also necessary that the experiment be made in an otherwise dark place.

In the experiments undertaken by the Committee of the Franklin Institute to determine the efficiency of the dynamo-electric machines placed in their hands, namely, the large and small Brush, the Wallace-Farmer, large and small, and one of Gramme's machines, care was taken, in order to make the measurements as accurate as possible, so to arrange the apparatus that no reflected or diffused light should fall on the photometer, and thus introduce an element of error.

The electric lamp was enclosed in a box open at the back for convenience of access, but closed with a non-reflecting and opaque screen during the experiments. Projecting from a hole in the front of the box was a wooden tube, 6 in. square inside and 8 ft. long, with its inner surface blackened to prevent reflection, thus allowing only a small beam of direct light to leave the box.

The beam of light passed into a similar wooden tube, placed at a proper distance from the first (about 30 ft.), and holding in its farther end the standard candle. This tube also held the dark box of a Bunsen photometer, mounted on a slide, so as to be easily adjusted at the proper distance between the two sources of light. A slit in the side of the tube enabled the observer to see the diaphragm and grease-spot. The outer end of the second tube was also covered by a non-reflecting opaque hood, and the room was, of course, darkened when photometric measurements were taken. The rigid exclusion of all reflected or diffused light is believed to be the only trustworthy method of obtaining true results, and will, no doubt, account in a great degree for the lower candle power obtained in these experiments than that given by many previous experimenters.

The difficulties encountered in the measurement of the light, arising from the difference in colour, were at first thought to be considerable, but further practice and experience enabled the observer to overcome them to such an extent that the error

arising from this cause is inconsiderable, being greatly less than that due to the fluctuations of the electric arc itself.

The Franklin Institute Committee considered what advantage would be gained by using a larger source of light than the standard candle, but after making several experiments with gas flames and the oxy-hydrogen light, they determined to use a standard candle only, making corrections for any variations in the rate of consumption of 120 grains per hour.

In determining the light-giving power of the current produced by the different machines, a continuous run of from 4 to 5 hours was made, and great care was taken to keep the axis of the two carbons of the lamp in the same line. To facilitate observations, a lens was placed in the side of the electric lamp box, in line with the carbon points. The axis of the lens was at right-angles to the beam of light going to the photometer, and an image projected upon a screen, from the lens, enabled the observer to note the condition of the carbon points without distressing the eye. Photographic views of the carbon points were also taken at the moment of making the photometric observations, and care was observed that, at the moment of making the measurement, there was no fluctuation or moving from side to side of the electric arc.

The first of the following tables exhibits the results obtained by the Franklin Institute from their photometric measurements of the lights from the Brush

TABLE SHOWING WEIGHT, POWER ABSORBED, LIGHT PRODUCED, ETC., BY DYNAMO-ELECTRIC MACHINES TESTED BY A COMMITTEE OF THE FRANKLIN INSTITUTE, 1877-8.

Name of Machine,	Weight.	Copper Wire in		Revolutions of Armature per minute.	Horse Power.	Light in Standard Candles.		Foot-lb. Power consumed per Candle.	Size of Carbons.	Length of Carbon consumed per hour.	
		Armature.	Field Magnets.			Total.	Per H. P.			+	-
Large Brush . .	lb. 475	in. .081	lb. .134	1,340	3.26	1,230	377	87.4	3 X 3	in. 1.78	.34
Small Brush . .	390	.063	.196	1,400	3.76	900	239	137	3 X 3	1.91	.58
Large Wallace . .	600	.042	.114	800	—	823	—	—	3 X 3	—	—
Small Wallace . .	350	.043	.098	1,000	3.89	440	113	292	1 X 1	2.45	.073
Small Gramme . .	366	.059	.108	800	1.84	705	383	85	1 X 1	3.15	.55

TABLE EXHIBITING DIMENSIONS, WEIGHT, LIGHT POWER, AND HORSE POWER ABSORBED IN THE MACHINES TESTED BY THE TRINITY BOARD, 1876-7.

Name of Machine.	Dimensions.		Weight.	Horse Power Absorbed.	Revolutions per Minute.	* Light produced in Standard Candles.		Light per H. P. (condensed).	Light per H. P. (diffused).	Sizes of the Carbons.
	Length.	Bredth.				Condensed.	Diffused.			
Holmes	in. 59	in. 52	cwt. lb. 51 35	3.2	400	1,523	1,523	476	476	3 X 3
Alliance	52	54	36 49	3.6	400	1,953	1,953	543	543	3 X 3
Gramme (No. 1) . .	31	31	25 56	5.3	420	6,663	4,016	1,257	758	3 X 3
" (No. 2)	31	31	—	5.11	420	6,663	4,016	1,257	758	3 X 3
Siemens' (Large) . .	45	29	11 74	9.8	480	14,818	8,932	1,512	911	3 X 3
" (Small)	26	—	3 84	3.3	850	6,864	4,138	2,080	1,254	3 X 3

* In this table, as it appears in Mr. Douglass's report to the Trinity Board, dated April 23, 1877, these columns are headed "Condensed Beam" and "Diffused Beam." In the copy of the same table as given in Mr. Douglass's paper, read at the Institution of Civil Engineers, March 25, 1879, the same columns are headed "Maximum" and "Mean" respectively.

machines, large and small; the Wallace-Farmer machines, large and small, and the small machine of Gramme, made by Breguet, and sent by him to the Philadelphia Exposition. The latter machine was lent by Prof. Wiley, of Purdue University, Lafayette, Indiana, and the others were sent in by their makers—the Brush by the Telegraph Supply Company of Cleveland, Ohio, and the Wallace by Wallace and Sons, of Asonia, Conn. The second table gives some particulars of the experiments made at the South Foreland by Mr. (now Sir James) Douglass, the engineer to the Trinity Board, in 1876 and 1877.

The measurements of electric lights made by the Franklin Institute, and those by the Trinity House authorities, thus include particulars of the chief machines then in use.

It is but fair to the proprietors of the Gramme machine, as tested by the Trinity Board, to state that the type of apparatus tried was not the best in use, and that the Gramme has since been found in practical working to very nearly reach the candle-power per horse-power of the smaller Siemens machine.

According to Messrs. Sautter and Lemonnier and Co.'s experiments, made by them in Paris, they give for the Gramme machines:—

A type 2,400	} Standard candles per H.P.
C type 2,800	
D type 3,125	

In the photometric measurements of the Trinity Board, the standard of comparison was the 6-wick

colza-oil lamp of the Board, and it was placed at a distance of 100 feet from the electric lamp. It was found that when two of Siemens' machines were coupled together, they gave a larger candle power than when worked separately. Working separately the aggregate light was equal to 12,403 candles, while the illuminating power rose to 14,134 candles when the machines were joined to one cable and driven at the same speed as before.

CHAPTER XI.

MATHEMATICAL AND EXPERIMENTAL TREATMENT OF THE SUBJECT.

Dr. Hopkinson's Investigations.—Dr. Hopkinson, in April, 1879, read a valuable paper on “Electric Lighting” before the Institution of Mechanical Engineers. In this communication he gives the results of experiments on one of Siemens’ continuous current dynamo-machines to establish the relation between the electromotive force, resistance of the circuit and current, and also between the energy transmitted, measured by dynamometer, and that appearing as current. The curve formed by taking the current as abscissæ and the electromotive force as ordinates when different resistances are in circuit, is given, the quantities being reduced to a common rate of 720 revolutions a minute, it being taken that electromotive force, with the other elements constant, is proportional to the speed. From this curve various problems can be solved. It will determine what current will flow at any given speed of rotation of the machine, and under any conditions of the circuit, whether of resistances or of opposed electromotive forces.

Mr. Schwendler's Experiments.—With regard to the relation of speed to currents and electromotive force, Mr. Schwendler* states: "The current produced by a dynamo-electric machine through a given constant total resistance in circuit increases permanently with the speed of the induction cylinder. This increase of current for low speeds is more than proportional to the speed; afterwards it becomes proportional, and for high speeds the increase of current is less than proportional to the speed. The current has, however, no maximum for any speed, but reaches its greatest value at an infinite speed. This same law, as the total resistance in circuit is supposed to be constant, of course holds good also for the electromotive force."

With regard to the influence of external resistance, Mr. Schwendler further states: "Keeping the speed constant, the electromotive force decreases rapidly with increase of external resistance. This decrease is more rapid the smaller the internal resistance of the machine. Hence the currents must decrease much more rapidly than proportional to the total resistance in the circuit. As in the case of speed the electromotive force has no maximum for a certain external resistance, but approaches permanently its greatest value for an external resistance equal to nil."

Mr. W. H. Preece's Investigations.—Mr. W. H.

* Précis of report to the Board of Directors of the East India Railway on electric light experiments.

Preece, in a paper on the Electric Light in the *Philosophical Magazine* of January, 1879, investigates mathematically the question of grouping lights in multiple arc and in series, and arrives at the conclusion that "beyond certain limits, when the current is produced by a dynamo-machine, if n lamps be joined in series the total light becomes diminished by $\frac{1}{n}$, and the light emitted by each lamp becomes diminished by $\frac{1}{n^2}$. If they are joined up in multiple arc the total light is diminished by $\frac{1}{n^2}$ and the light emitted by each lamp $\frac{1}{n^3}$. In the latter case the rapid diminution in the light emitted is due to the fact that the heat is developed in the machine itself instead of in the resistances external to it."

Mr. Preece then goes on to say, "We have assumed W (*i.e.* the work done in the steam-engine in unit time) to be constant; but this is only the case when the velocity of the rotating coils in the dynamo machine has attained a maximum. This limit will vary with each dynamo machine and each kind of lamp used. With the Wallace-Farmer machine the limit appears to be reached when six lamps are connected up in series. With the Gramme alternating machine and Jabloch-koff candles the limit appears to be five lamps. Beyond these limits the above laws will be true. It is partial success in multiplying the light that

has led so many sanguine experimenters to anticipate the ultimate possibility of its extensive subdivision—a possibility which this demonstration shows to be hopeless, and which experiment has proved to be fallacious.”

Mr. Alexander Siemens' Paper at the Society of Telegraph Engineers.—Mr. A. Siemens has pointed out, in a paper read before the Society of Telegraph Engineers in March, 1880, that in the ordinary dynamo machines as generally used, “the intensity of the magnetic field in which the armature revolves varies very much, being greatest when the external resistance is smallest, and *vice versa*. If, therefore, the lamps producing the light are not working very regularly, their action re-acts continually on the machine in the most unfavourable way, by weakening the magnetic field when the resistance is greatest and the current most wanted, and by inducing the most powerful currents when the least resistance is to be surmounted.” This often destroys the insulation of the wire.

To obviate this the electro-magnet circuit has been made a parallel circuit to the external resistance circuit, one circuit acting as a shunt to the other. In this case, as the external resistance increases the E. M. F. rises, as more current passes through the electro-magnet circuit.

But although this causes the E. M. F. to vary in the right direction, it still causes fluctuation, and the variation in the strength of the field-magnets causes a variation in the power absorbed, and

also displaces the most favourable point for the brushes.

A constant and permanent magnetic field is therefore recommended by using a separate machine for exciting the electro-magnets.

It is also pointed out that length of leading wires, by adding to the resistance of the circuit, diminishes the fluctuations in the current caused by the variation in the resistance of the arc.

Alternate-current machines appear, according to Mr. Siemens, to stand wear and tear better than the continuous-current machine, and in those made by Mr. Siemens an important improvement has been introduced by omitting the iron cores of the revolving coils. The heating effects of the cores caused by the incessant reversing of their polarity is thereby avoided, and the intensity of the magnetic field scarcely affected.

Mr. Fitzgerald's Investigations.—It has been remarked by so able an investigator of electrical phenomena as Mr. Fitzgerald, that there is no force in nature varying simply as the number of cells in series of a battery or corresponding with what is known as electromotive force, and no inertia varying according to what is defined as electrical resistance.

Further, it is observed that the effects of varying those "current elements" are very different in the two cases of the dynamo-electric and the voltaic currents. The law of Ohm, as previously applied to the current effects of voltaic batteries, was thought

by some to be inapplicable in certain points to the dynamo-electric machine and its currents. This does not mean, however, that the well-known law of Ohm is incorrect as a law of phenomena—an expression indicating a necessary relation—but from a physical point of view as empirical as other mathematical laws in which causation is lost sight of.

In the case of any electro-motor the equation $I = \frac{E}{R}$ is perfectly applicable. In the voltaic battery, however, a variation of R does not of necessity affect E , which is altogether independent of such variation when this occurs in the external portion of the circuit. Thus we have generally $I \propto \frac{E}{R}$, or current varies inversely as the resistance in circuit.

A variation of E does not necessarily affect R ; and, when the external resistance of the circuit bears a high ratio to the battery resistance, a variation of the electro-motive force from E to E^1 —an addition to, or diminution of, the number of cells in series—causes the current to vary approximately in the ratio $\frac{E^1}{E}$. Accurately, the variation in any case is determined by the ratio $\frac{E^1 R}{E R + E \rho}$, where ρ is the resistance of the cells added or subtracted. Thus,

$$\frac{E}{R} \times \frac{E^1 R}{E R + E \rho} = \frac{E^1}{R + \rho}.$$

In the case of a telegraph circuit, for instance,

we have approximately $I \propto E$. On the other hand, in the dynamo-electric machine, converting into electrical work a given horse-power, $I \propto \frac{1}{\sqrt{R}}$, since,

the ratio $\frac{E^2}{R}$ being constant, $E^2 \propto R$, $E \propto \sqrt{R}$, and

$\frac{E}{R} \propto \frac{\sqrt{R}}{R} = \frac{1}{\sqrt{R}}$. Thus any variation of R in this case necessarily affects E .

Again any variation of E necessarily affects R ; and, the product $E I$ being constant, we have

$I \propto \frac{1}{E}$, a somewhat startling result, which, to some observers, has appeared contradictory to the law of Ohm. With this, however, it is in perfect accord—in effect, since $E \propto \sqrt{R}$, $R \propto E^2$, and

$$\frac{E}{R} \propto \frac{E}{E^2} = \frac{1}{E};$$

or, when E is varied, the current varies inversely as the electro-motive force, because the resistance varies as the square of this value.

It will be seen that $R \propto E^2 = \frac{1}{I^2}$, and that the same quantity of work will be done by the current whatever may be the resistance in the circuit.

If h. p. be taken to express the total horse-power converted into electrical work (in the whole circuit), under the best conditions, with a Gramme machine of the form experimented with at the Franklin Institute,

$$H. P. = h. p. \times 1.39,$$

and the efficiency of the machine is expressed by

$$\frac{\text{h. p.}}{\text{H. P.}} = .72 \text{ (nearly).}$$

Or the machine can convert into electrical work 72 per cent. of the energy expended upon it.

Let E = electromotive force, in volts, acting in a circuit.

R the total resistance, in ohms, of the circuit.

r = resistance of the voltaic arc obtained.

H. P. = h. p. of the prime motor working the dynamo-electric machine.

h. p. = the h. p. absorbed in the production of electrical work in the circuit.

λ = the intensity, as standard candles, of the electric light so arranged as to illuminate equally in all directions.

Λ = intensity of the light in one particular direction; the light being arranged to give the maximum illumination (without reflectors) in this direction.

The energy of the current, or the mechanical equivalent of the work and heat produced by it *per hour*, will be

$$W = \frac{E^2 \times 2654}{R} \text{ ft.-lbs.} = \frac{E^2 \times 1.18}{R} \text{ ft.-tons.}$$

Horse-power absorbed in the current

$$\left(\frac{\text{energy in ft.-lbs.}}{33,000 \times \text{time in min.}} \right)$$

will be

$$\text{h. p.} = \frac{E^2}{R \times 747}.$$

The ratio $\frac{h. p.}{H. P.}$ is the measure of the efficiency of dynamo-electric machines. In the case of Gramme's machine, under the best conditions we have

$$H. P. = h. p. \times 1.39.$$

The horse-power absorbed in the arc itself is

$$h. p. \times \frac{r}{R}$$

The ratio of this latter value to $h. p.$, or

$$\frac{r}{R} = \frac{h. p. \times r \times 747}{E^2}$$

is the measure of the efficiency of the electrical circuit in the production of the greatest quantity of light with a given quantity of electrical energy.

In the experiments with the Gramme machine made by the Committee of the Franklin Institute, the light, in standard sperm candles, produced by the voltaic arc was

$$\lambda = h. p. \times \frac{r}{R} \times 1,044 \text{ (candles)} \dots (I)$$

when the intensity of the light was approximately equal in every direction. But, when the carbons are so adjusted as to give the best effects with the photometer in a given position, we may multiply the former value by 2.87, and we have

$$\Lambda = h. p. \times \frac{r}{R} \times 2,996 \text{ (candles)} \dots (II)$$

Expressing these equations in a different form, we have

$$\lambda = I^2 r \times 1.4 \dots (I a)$$

$$\Lambda \times I^2 r \times 4 \dots (II a)$$

It should be remembered that these values are obtainable only under the most carefully arranged conditions.

Although the light cannot be subdivided without very considerable loss, it is not to be admitted that, if a given total quantity of light be produced with one hundred lamps, it is one hundred times as expensive as if it were produced by one lamp. If we use two lamps instead of one, and put them in series, the original arc resistance, l , is not necessarily doubled; indeed it may be preserved constant, in which case we should have $\frac{C^2 l}{2}$ for each light, and the original value, $C^2 l$, for the two. And if we place four lamps in parallel circuit, the total resistance may be reduced nearly fourfold, so that we may obtain twice the original current with half the electromotive force in action. Thus

$C^2 l$, or $\frac{E^2}{l^2} l$ becomes

$$\left(\frac{E}{2}\right)^2 \left(\frac{l}{4}\right)^2 \times \frac{l}{4} = \frac{4 E^2}{l^2} \times \frac{l}{4} = C^2 l.$$

The theoretical value for each light being

$$\left(\frac{C}{2}\right) l = \frac{C^2 l}{4},$$

and that from the four $C^2 l$. The loss, when the light is subdivided, is doubtless due to an increase in the quantity of heat which must be expended before any luminous effect is produced.

Equational numbers required in reducing results.—

The particulars given herewith will be found of value in any experiments upon dynamo-electric machines, circuits, or lamps.

One horse-power is equal to 1,980,000 foot-lbs. per hour, or 33,000 per minute; that is, 33,000 lbs. weight falling one foot in a minute, or 1 lb. weight falling 33,000 feet per minute.

1 horse-power is maintained in modern steam-engines with $3\frac{1}{2}$ lbs. of coal per hour.

1 heat unit = 772 foot-lbs.

Therefore, 1 horse-power = 2,565 units of heat per hour, and $\frac{2.565}{3.65} = 6\frac{3}{4}$ units of heat per candle of light.

1 standard candle (of sperm) burns 120 grains per hour, and equals $\frac{1}{3}$ cubic feet of gas per hour.

1 lb. gas coal produces 4 cubic feet of gas, 0.85 lb. of gas coke, and 0.05 lb. of tar. In a pound of gas coal there are 15,000 units of heat, in the coke 13,000, in the gas tar 20,000 units of heat.

The power expended by a dynamo-electric machine producing current for the light of a standard candle is about 90 lbs. falling through one foot in a minute.

1 calorie (kilogramme of water heated 1° Centigrade) is equal to 424 kilogrammètres, which equals 3.9683 units (Fahrenheit).

1 kilogrammètre equals 7.2331 foot-lbs.

The electrical units employed at present may, for practical purposes, be taken as follows:—

The *Volt* is the unit of electro-motive force, and

is nearly equal to the electro-motive force of a Daniell element, the latter being about 1.079 *volts*.

The *Ohm* is the unit of resistance, and equal to 485 mètres of pure copper wire one millemètre in diameter at a temperature of 32° F.

The *Ampère* is the unit of current, and is the current that would be produced by an electro-motive force of one volt, acting through a resistance of one ohm.

CHAPTER XII.

PRESENT APPLICATION AND COST OF THE ELECTRIC LIGHT.

SO extensive has been the introduction of electric light, that to enumerate the installations and dwell upon them in detail would in itself almost fully occupy the pages of this little treatise. The more noteworthy instances can only, therefore, be briefly glanced at.

Interior Illumination of Large Buildings.—Such places as halls, workshops, and picture-galleries are most effectually illuminated by arc lights from above. There are various ways of doing this, and of diffusing the light. Perhaps the best is that of sending the full rays through a large sheet of frosted glass.

This should be set in the centre of the ceiling, if convenient at the same height as the ceiling. Its size will depend upon the size of the building. For a medium-sized theatre, a glass surface 6 feet square will be found sufficient. Directly above this frosted glass surface is to be placed the electric light. The lamp should be hung by a cord and counterpoise, and if it be of the form described at

page 229, no other arrangement will be necessary, because the rays of light from this lamp are all thrown downwards. If another form of lamp be used, it will be necessary to reflect the light downwards from it by means of wooden covers, about 6 feet square, covered with sheets of tin plate. Two of these will be found sufficient. They should be set at an angle, rising from the edges of the frosted glass until quite over the lamp. Any rays then thrown upwards will be reflected upon the frosted glass.

Light sent over a building in this way is beautifully diffused, and is very soft and agreeable. It will be necessary to have free access to the lamps from above. In some cases it will be found very advantageous to enclose the lamp in a ground-glass case, and to suspend this near to a white ceiling. But a better plan still is to have a pyramidal case of ground-glass made, to fasten the base of this to the ceiling, and to lower the lamp into it from above. The result is perfect diffusion of the light, which must of course be reflected downwards into the glass case by reflecting boards or a whitened ceiling.

Workshops are usually illuminated by setting the lamp over a reflector on the floor, screened by some cover, and projecting the rays from the reflector upon the whitewashed ceiling. This is what is usually done, and is found to answer the purpose very well. A great objection to the Serrin and such lamps is the base containing the move-

ment, which, when the lamp is suspended, throws downwards a great deal of shadow; but this is entirely prevented by the use of slanting reflectors.

In the extensive chocolate works of M. Menier the Serrin lamps are in use, and the proprietor has devised a means of access to the suspended lamps without the use of ladders or a separate suspension cord. A windlass is used, having a dry wooden drum with cast-iron cheeks. A cable with two insulated and stout wires is made fast to the drum, and the ends of it to the cheeks; this cable leads upwards to the roof, over a pulley, and on the other side hangs the lamp. It can thus be lowered by the windlass with ease without in any way disturbing the connections. The cheeks of the winding drum are, of course, connected to the terminals of the dynamo-electric machine through the separated bearings.

Electric arc lights are in extensive use in all out-of-door works of magnitude, such as bridge and dock construction, and it is found, as was proved in the case of the great Tay bridge, that operations may be carried on at night with the greatest facility. For such purposes, the light should be so arranged that a power of about 2,000 candles is thrown around every 600 feet of space—that is, an ordinary 2,000 electric light, placed upon a 20-foot standard, should give sufficient illumination at a radius of 300 feet. In some cases the standard is thus inadmissible, and the light may have to be thrown upon

the work from a parabolic reflector. All such lights should be enclosed simply in a clear glass case to screen them from the wind.

The use of ground-glass cases for these purposes, and above all opalescent glass of any density, should be avoided as much as possible. A great deal of light is thus lost in the Jablochhoff system. It has been found from experiment that

Plain glass absorbs about	10 per cent.
Ground or frosted	30 „
Thin opalescent	45 „
Thick ditto	60 „

When the light is any considerable distance from the machine, the cables carrying the current should be thick and of good copper, and every means thus used to reduce the resistance of the conductor outside the machine, more especially when a lamp with long carbons, and consequently much resistance, is employed.

The use of the electric light in our lighthouses is a matter of great importance, but not of special interest to the general public, so that, with the exception of what has been said in connection with the experiments on dynamo-electric machines, it need not further occupy space.

For use aboard ship, and for war vessels especially, a very useful apparatus is manufactured by Messrs. Sautter and Lemonnier. It is a lenticular projector, with a Fresnel lens, composed of three dioptric and six catadioptric lenses. The Serrin lamp is placed behind the system, which is mounted

on an iron stage, movable around its vertical axis, and turning upon its horizontal axis, so that the light has great range, and may be concentrated upon one point anywhere around the vessel. The whole is enclosed in a cylinder, opaque behind; and a small camera lucida is so placed in it as to throw the image of the carbon points upon a ground-glass screen, so that their condition may be noted without opening the cylinder. The three-cylinder Brotherhood direct engine is usually employed to drive the machine in conjunction with such apparatus. Mr. Wilde has supplied most of the machines and lamps for our navy, and Mr. Siemens for the War Office.

The incandescence lamps have been now for many months used in the Savoy Theatre, London, both before and behind the curtain, and even in the decoration of the actresses. This system is also extensively used in houses, shops, streets, railway trains, and ships, and is generally much more adapted to domestic lighting than the arc system.

Cost of Electric Light.

In entering upon a consideration of this aspect of the question, the greatest care is necessary in order that the data may be of a thoroughly trustworthy character.

Mr. A. Siemens, in his paper read before the Society of Telegraph Engineers, March, 1880, gives the following particulars as regards comparative cost of electric light and gas. In making the

comparison it is assumed that a 100-candle Sugg gas-burner will consume 23 cubic feet of gas per hour, costing 3s. 6d. per 1,000 cubic feet: further, that a 400-candle alternate-current light requires $\frac{1}{2}$ horse-power, and that it consumes 3 inches of carbon per hour, costing $4\frac{1}{2}$ d. per foot; and that a 6,000-candle continuous-current light requires 4 horse-power, consuming 3 inches of carbon per hour, costing 8d. per foot. When the electrical machines are driven by a gas-engine consuming 26 cubic feet of gas per hour per horse-power, the relative cost of maintaining a light of 6,000-candle power is as follows:—

For gas 4s. 10d.

For alternate current electric lights (fifteen 400-candle lights):—

200 cubic feet of gas for the motor	s.	d.
	0	8 $\frac{1}{2}$
3 feet 9 inches of carbon, at $4\frac{1}{2}$ d. per foot	1	4 $\frac{1}{2}$
Attendance		6
	2	7

Showing a saving of 47 per cent. over gas.

For continuous current light:—

114 cubic feet of gas for the motor	s.	d.
	0	4 $\frac{1}{2}$
3 inches of carbon, at 8d. per foot		2
Attendance		1 $\frac{1}{2}$
	0	8

Showing a saving of 87 per cent. over gas.

At the Albert Hall a saving in gas is effected of 25,000 cubic feet per night, or £4 7s. 6d., while the five electric lights cost £1 10s. 6d. for fuel, attendance, and carbons. In this case a pumping

engine is used for driving the machinery, which consumes a very large quantity of fuel, and nevertheless a saving of 66 per cent. is effected.

At the British Museum the electric light was used for 360½ hours between 28th Oct., 1879, and the end of February, 1880. Two 8 horse-power engines are used. There are four lights in the Reading-room, of 4,000 candle power each, and in the halls seven of 400 candles each. There are four continuous-current machines for the Reading-room lamps, one to each lamp, in separate circuits. One alternate-current machine works the other seven lights. Another machine of continuous-current type excites the electro-magnets of all the other five. The machines are tried in the morning, and then the fires of the engines are banked up so as to be ready at 10 minutes' notice.

The cost for 360 hours is as follows :—

	£	s.	d.
Carbons	50	15	10
23 tons of coal, at 15s.	17	5	0
18 gallons of oil, at 4s. 6d.	4	1	0
54 lbs. of waste, at 6d.	1	7	0
2 sets of brushes, at 5s.	0	10	0
1 set of commutator plates	0	17	6
Engine-driver, 18 weeks at 37s.	33	6	0
Total cost	£108	2	4

This gives us cost per hour :—

	s.	d.
For carbons	2	9
Other charges	3	3
	<u>6</u>	<u>0</u>

for a light of 18,800 candles; which amount of

light produced by gas would cost at least 15s. per hour, the saving effected being 60 per cent.

The following facts as to the lighting of the Thames Embankment will be of interest. The first experiment, with 20 lights, was commenced on the 13th of December, 1878; the second, with 40, on the 16th of May, 1879; the third, with 55 lights, on the 10th of October, 1879. The length of the circuit on the west side of Waterloo Bridge is 6,007 ft.; of that on the east side, 6,062 ft. The total length of conducting wire is 17 miles 361 yards. The ten new lights on Waterloo Bridge are worked by a 20-light Gramme machine in two circuits.

The following are a few particulars of Messrs. Siemens' machines, &c.:—

Alternating-current machine, large size.

Dimensions, $29\frac{1}{2}'' \times 27\frac{1}{2}'' \times 34''$.

Weight, 8 cwt. 0 qrs. 13 lbs.

Speed, 600 revolutions per minute. Price . . . £ 137

Small dynamo-machine for magnetising the above. Speed

1,000 revolutions per minute. Price . . . 45

£182

Capacity for 12 lamps in one circuit, or two circuits of 6 lamps each. Each lamp of 400-candle power. Total power absorbed about 9 horse-power.

Smaller alternating-current machine.

Dimensions, $28'' \times 19\frac{1}{2}'' \times 24''$.

Weight, 5 cwt. 0 qrs. 20 lbs.

Speed about 700 revolutions per minute. Price . . . £ 87

Small dynamo-machine for magnetising . . . 38

£125

This machine feeds 6 lamps of 400 candles each in one circuit, and absorbs 5 horse-power.

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